

## **Employer's Requirements: Technical Specifications**

**DESIGN, MANUFACTURE, SUPPLY, TESTING, COMMISSIONING AND  
TRAINING OF 378 NOS. OF STANDARD GAUGE METRO RAIL CARS  
FOR MUMBAI METRO RAIL INVESTMENT PROJECT**

**CONTRACT AGREEMENT**

**CONTRACT 'MRS1'**

**PART-I**

**SUPPLY REQUIREMENTS**

**EMPLOYER'S REQUIREMENTS: TECHNICAL SPECIFICATIONS (ERTS)**



000354



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## 1. INTRODUCTION

### 1.1 Scope

- 1.1.1 This specification establishes requirements for the design, development, manufacture, supply, testing, delivery, commissioning and integrated testing of light weight fully furnished modern passenger cars with microprocessor control 3-phase induction motor drive and suitable for Unattended train operation conforming to Grade of Automation-GOA4 as specified in IEC62290-1:2006 or latest, including the training of operating and maintenance staff of the Project Owner, for line 2 and 7 of the Mumbai Mass Rapid Transit System. The trains shall initially be operated in 'GOA2/GOA3' and shall be progressively used in 'GOA4'. The underground and elevated sections have ballastless track, and at-grade sections have ballasted track. The cars shall be designed to meet the performance requirement given in Chapter 3 of this specification. The track gauges for elevated, at grade and underground corridors shall be 1435mm.
- 1.1.2 The cars required for the various Lines shall be delivered and commissioned by the Contractor at the nominated Train Maintenance Depots of the Project Owner. The Contractor shall base his Testing, Commissioning Organization and Maintenance Organization at the nominated depots.
- 1.1.3 The scope shall also include the following:
- (i) To provide all the documentation and support material associated with the operation and maintenance of the cars as specified in the tender document for all the corridors.
  - (ii) Ongoing technical support and Defects Liability coverage until the completion of the warranty period, and rectifying the defects and deficiencies as communicated by the Engineer.
  - (iii) Interfacing with other Designated Contractors who have either physical, functional or design interfaces with this contract.
  - (iv) Training of engineers, operations and maintenance staff including providing the training materials, training kits and demonstration equipment.
  - (v) Initial supply and installation of all consumables and materials required for testing, commissioning and operation.
  - (vi) To provide final drawings, design calculations and other documents including operations and maintenance manuals for review and acceptance by the Engineer.
  - (vii) To provide supporting information including samples for design development items such as mock-ups, studies and reports.
  - (viii) Supply of spares, special tools, special test and diagnostic equipment and special training equipment, in sufficient quantities to meet the maintenance requirements.
  - (ix) Preparation of documents for obtaining approvals by Employer from the appropriate statutory authorities.
- 1.1.4 Complete network will be electrified at 25kV AC single phase, 50Hz with auto-tensioned catenary and contact wire in the elevated and at-grade sections, and overhead rigid catenary in the underground section.
- 1.1.5 Following types of cars and configuration shall be adopted: -

- DM : Driving Motor cars,  
 T : Trailer car with pantograph  
 M : Non-driving Motor cars.

The rake formation shall generally be as follows:

- 3 Car unit formation: \*DM – T – M –  
 6 Car train formation: \*DM – T – M – M – T – DM\*

For increase in quantity (if required):

- 2 Car train formation: – T – M –  
 8 Car train formation#: \*DM – T – M – T – M – M – T – DM\*



Where:

- \* automatic couplers having mechanical and pneumatic coupling (without electrical head)
- Semi-permanent couplers
- # In case of 8 Car formation (if required), the performance features of extra 2 Car unit (T-M) shall be suitably designed in line with ERTS sub clause 3.22.10.

1.1.6.1 One of the end car of train i.e. DM car shall be having more seating capacity with additional comfort features and shall be treated as 'First Class' car.

1.1.6.2 The 'First Class' car shall be separated from other cars of the train by means of a sliding door. Additional details on passenger capacity, seating and sliding door for 'First Class' car are mentioned in ERTS sub clause 3.21.4, 4.14.4(vi) and 7.8 respectively. Details of design for 'First Class' car shall be discussed and approved by the Engineer during design stage.

However, the requirement of 'First Class' Car or otherwise will be reviewed and finalized during design stage, Bidder shall provide reduction in Bid Total Lump Sum Price for non-provision of 'First Class' DM car in their Financial Bid as mentioned in Part-I: Section-4: Bidding Forms: Annexure PBS to Price Bid Submission Sheet.

1.1.7 The scope of work includes all items of work which may be required to meet the performance requirements, trouble free and efficient operation of trains and meeting the best international practices even if not specifically mentioned in the tender specifications.

1.1.8 The trains may have to be operated in GoA2/GoA3 modes with driver/ attendant during initial phase of the project and shall finally be upgraded to GoA4 (UTO).

## 1.2 Prototype Train

1.2.1 The prototype 6-cars train shall be supplied as per the delivery schedule.

1.2.2 Clearance for dispatch of the prototype trains will be granted, only after successful completion of tests at the nominated place by the Manufacturer, to the entire satisfaction of the Employer. Should any modification/ alteration based on results of the tests on the prototype be required, Contractor will be obliged to carry out necessary modifications at no additional charge on all trains.

1.2.3 The Contractor shall manufacture and supply complete six cars train duly equipped with test and measuring equipment and sensors, for carrying out the following tests, in addition to those specified in IEC 61133 or an accepted International Standard, on respective lines.

- (i) Oscillation test to prove the riding and stability performance of the cars - for confirming the fitness of vehicle for introduction into revenue service.
- (ii) Performance requirement test including test of energy consumption.
- (iii) Tests to determine the levels of interference with traction power supply and signal and telecommunication train control equipment and facilities, to prove that these are within acceptable limits.
- (iv) Emergency Braking Distance test for AW0 and AW3 conditions under dry and wet conditions.
- (v) WSP tests under reduced adhesion conditions.
- (vi) Any other test considered necessary for safe running of rolling stock or desired by Employer.

1.3 Contractor shall seek clearance for dispatch of each train set including prototype train set from the Engineer and shall dispatch the train only after the Engineer's clearance. Clearance for dispatch of the each of balance trains can be given by the Engineer even before successful completion of tests on the prototype trains as per clause 1.2.3 above with the provision that should any modification/ alteration based on results of the above tests on the prototype or otherwise be required, contractor shall be obliged to carry out necessary modifications at no additional charge on all trains.

1.4 During initial phase of the project, all trains (including prototype train) shall be tested and commissioned for GoA2 modes of automation. Upgradation of all trains to GoA3/GoA4 modes shall be done subsequently (refer Note No. 6. of 'Attachment to Appendix FB-1' to 'Form of Bid'). The interface testing may have to be done separately for line 2 & 7 of Mumbai Metro.

- 1.5 In case of any contradiction in the requirements noted in different chapters of ERTS, the specifications noted in the chapters dealing with specific sub-systems shall prevail over the specifications noted in other chapters.



## 2. GENERAL REQUIREMENTS

### 2.1 General

2.1.1 This Chapter covers the following requirements:

- (i) Interface Activities
- (ii) Quality Assurance
- (iii) System Safety Assurance
- (iv) Hazard Analysis
- (v) Reliability
- (vi) Availability
- (vii) Maintainability
- (viii) Electromagnetic Compatibility
- (ix) Noise and Vibration
- (x) Fire and Toxicity Standards
- (xi) Life Cycle Costing

### 2.2 Interface Activities

2.2.1 Interfaces exist between the Rolling Stock Contractor and other designated Contractors for systems, where the systems are mutually dependent, or interactive for satisfactory and safe operation. The Rolling Stock Contractor shall maintain close coordination / interface during design, manufacturing and, testing and commissioning phase with the designated Contractors, various other Contractors and Consultants who may be working in the Project, whether or not specially mentioned in the Contract. The Rolling Stock Contractor shall perform all design duties and provide all materials, equipment and labour to ensure the satisfactory accomplishment of interface of the systems for which the Rolling Stock Contractor is responsible.

2.2.2 The Rolling Stock Contractor shall submit and maintain an agreed Interface Management Plan. At all stages of the work, all interfaces shall be discussed and agreed upon between the Rolling Stock Contractor and other Designated Contractors. Interface shall be with Signalling, Communications, Power Supply, Platform Screen Door (PSD), Civil Engineering, Track-work, Depot, Pit Wheel Lathe (PWL) Contractors and other Contractors advised by the Engineer. However, the Rolling Stock Contractor shall keep the Engineer apprised in writing of all such discussions, agreements and conclusions. Refer to the Employer's Requirements - General Specification for requirements of the Interface Management Plan, its scope and other related details.

2.2.3 In certain cases, the Engineer may direct the Contractor to liaise with Designated and other Contractors through the Engineer to discuss and agree on interfaces. However, the Rolling Stock Contractor shall keep the Engineer apprised in writing of all such discussions, agreements and conclusions.

2.2.4 It will be the sole responsibility of the Contractor that interface requirements be finalized timely. Any delays and consequential implications as a result of delay in such liaisons on account of reasons attributable to the Contractor, as concluded by Engineer, shall be the sole responsibility of the Contractor.

2.2.5 It would be the responsibility of the Contractor to settle all disagreements with the Designated Contractors. If such disagreement cannot be resolved by the Contractor, despite having made all reasonable efforts, then the Contractor shall refer the matter to the Engineer for resolution with complete details with supporting documents and any other information as may be required by the Engineer. The decision of the Employer shall be final and binding on the Contractor(s).

As part of MPR (Monthly Progress Review), the Contractor shall submit the details of all interface meetings held in corresponding month in tabular form enclosing MOM of each interface meeting.

Additionally, the schedule of interface meetings planned for next month along with the agenda (major issues to be discussed) for the same shall also be submitted as part of MPR submissions.

2.2.6 A Document titled "Interfaces between Rolling Stock, Signalling and Telecommunications Contractors" detailing the interfacing requirements and division of responsibility between the identified Designated Contractors is enclosed as 'Appendix TD' to this Specification.

- 2.2.7 It will be the responsibility of the Contractor to ensure that full potential of the rolling stock capability as specified is utilized by the Signaling Contractor(s). Any dilution shall be immediately brought to the notice of Engineer. The Contractor shall advise the maximum safe speed to the Signaling Contractor so as to enable the Signaling Contractor to design their system for 80Kmph of operational speed.
- 2.2.8 The Contractor, as a part of its Management team shall mobilize at site an Interface Manager (IM) as laid down in ERGS clause 2.3.2.
- 2.2.9 The Contractor shall engage an internationally reputed consulting agency not later than six (06) months from the commencement date for assisting the Contractor in all interface activities with other designated contractors. The Contractor's proposal for engaging consulting agency with detailed terms of reference (ToR) indicating detailed scope of work of interfacing with other designated contractors, the CV of proposed Interface Consultant to be positioned at site and timely submission of interface documents to the Engineer shall be submitted to Engineer for approval not later than three (03) months from the commencement date. The above Interface Consultant of the appointed consulting agency should be mobilized to the project site office in Delhi/Mumbai not later than six (06) months from the commencement date and shall continue to remain mobilized till the target MDBF of 125,000 km is met and accepted by the Engineer.
- 2.2.10 Employer at its sole discretion may appoint an internationally reputed consulting agency starting from three (03) months of the commencement date. The consulting agency shall assist Employer in verification and approving of the interface documents, as well as other design documents submitted by the Contractor and also for testing and commissioning etc. Under this contract with the consulting agency, services of experts up to Fifty (50) man-months can be utilized by the Employer.

In addition, the appointed consulting agency or any other agency appointed by Employer may be directed by Employer to undertake specific work related activities (both at off-site as well as at site). Also, for the work related activities, Employer at its sole discretion may depute its representative(s) to off-sites for discussion, inspection, testing etc. The expenditure for the above activities shall be borne by the Contractor but overall expenditure for these activities shall not exceed equivalent expenditure for deployment of experts for cumulative period of twenty (20) man-months only.

Total expenditure (total equivalent to 70 man-months) for deployment of experts at site as well as for other above said work related activities as mentioned above shall be borne by the contractor. The payments/reimbursements by the contractor for this shall be affected in accordance with the instructions issued by the Engineer from time to time during the contract execution.

In case of under-utilization or non-utilization of man-months, a recovery at the rate as decided by the Engineer shall be made from the payables to the Contractor.

### 2.3 Quality Assurance

- 2.3.1 The Contractor shall submit 'Quality Assurance Plan' for review and acceptance by the Employer as specified in the Employer's Requirements: General Specification. As a part of QAP, the Quality Assurance organization, proposed to be deployed by the Contractor for manufacture, testing and commissioning and DLP period, complete with CVs of key QA personnel shall have approval of the Engineer.
- 2.3.2 The Contractor shall develop a 'Quality Assurance Programme' (QAP), structured in accordance with acceptable international standards. Adequate records of quality assurance controls shall be maintained as per QAP and in a manner to facilitate performance audits by the Engineer.
- 2.3.3 The Contractor shall be solely responsible for all the Quality Assurance functions required by the Contract. All work and material shall be produced and control in accordance with an Internationally recognised and accepted quality standard.
- 2.3.4 All deliverable items of equipment shall be of the same configuration and be totally interchangeable. Any modifications performed on later deliveries shall be applied retrospectively to equipment already installed.
- 2.3.5 Overall responsibility of quality for manufacture, testing, commissioning and DLP shall lie with the Consortium member based on whose experience and strength, the Tenderer has qualified for this tender.

### 2.4 System Safety Assurance

- 2.4.1 The Contractor shall submit 'System Safety Assurance Plan' for review and acceptance by the



Engineer as specified in the Employer's Requirements: General Specification.

2.4.2 The System Safety Assurance Plan shall cover design, manufacture, testing, commissioning and integrated testing, and minimising the magnitude and seriousness of events or malfunctions, which could result in injury to patrons or staff and damage to equipment or property, but cannot be completely eliminated.

2.4.3 All personnel deployed by the Contractor in DMRC premises should have undergone requisite training on safety and should have the necessary valid certification from concerned authority.

## 2.5 Hazard Analysis

2.5.1 The Contractor shall take lead role in the interface Hazard Analysis for train borne equipment provided by other Contractors.

2.5.2 The Contractor shall produce the Hazard Analysis Schedule for the complete train including all train borne systems and shall interface principally with the Signalling, Communication, Power Supply, Civil and Depot Contractor as well as any other Designated Contractors to obtain the information necessary, from their hazard analysis, to complete the analysis.

2.5.3 The Contractor shall, as part of the safety analysis, prepare analysis to identify Hazards and ensure their satisfactory resolution. The following analysis shall be prepared and submitted by the Contractor for the Engineer's acceptance.

- (i) Preliminary hazard analysis
- (ii) Interface hazard analysis (excluding EMI)
- (iii) Subsystem hazard analysis
- (iv) Operating hazard analysis including maintenance
- (v) Quantitative fault tree analysis
- (vi) Failure modes effects and criticality analysis (FMECA)

2.5.4 The Hazard Analysis shall be carried out in accordance with EN50126 as the primary standard, or any other internationally accepted equivalent standard in areas not adequately addressed by the former standard.

2.5.5 The Contractor shall compile a list of critical and catastrophic items identified as a result of hazard analysis, FMECA or by other means. The Contractor shall carryout the Hazard and FMECA for the following equipment / sub-systems / systems:

- (i) Bogie and Suspension
- (ii) Vehicle Body
- (iii) Transmission Drive System
- (iv) Gangways
- (v) Coupler
- (vi) Brake System
- (vii) Door System
- (viii) HVAC System
- (ix) Pneumatic System
- (x) Communication System
- (xi) HV and Propulsion System
- (xii) Auxiliary Power System
- (xiii) Control equipment
- (xiv) TCMS
- (xv) Any item as deemed necessary by the Engineer.

2.5.6 All hazard resolution by procedural control shall be cross-referenced from the Critical and



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Catastrophic Items List to the appropriate manuals.

2.5.7 The qualitative measures of hazard severity are defined as follows:

- (i) Hazard Category I – Catastrophic: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies may cause death or system loss. The safety target shall be based on internationally accepted standards.
- (ii) Hazard Category II – Critical: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies may cause severe injury to personnel, severe occupational illness or major system damage.

The safety target for the occurrence of all Category II hazards summed together shall again be based on internationally accepted standards.

- (iii) Hazard Category III – Marginal: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies, may cause minor injury to personnel, minor occupational illness or minor system damage.
- (iv) Hazard Category IV – Negligible: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies will not result in injury to personnel occupational illness or damage to the system.
- (v) The Contractor shall submit a Schedule for Hazard Analysis Submissions within 30 days of Commencement Date (CD) and the Preliminary Hazard Analysis shall be submitted within 6 months of Commencement Date. This draft shall include a comprehensive assessment of potential equipment failure modes during normal operating and overload conditions and assess the performance of the equipment for a range of hazard conditions. The final draft shall be submitted by the completion date of final design.

2.5.8 The Contractor shall prepare a Fire Safety Design Report for review and acceptance by the Engineer. This shall be submitted within 2 months of Commencement Date and revised and updated for the completion of the preliminary, pre-final and final design stages. The design and materials used in the cars shall conform to fire safety requirements of EN 45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions as a minimum or better international standards applicable for similar Metro for underground operations with front evacuation, subject to the acceptance of the Engineer.

The Contractor shall engage an internationally reputed agency for the audit and certification of their fire safety design report. The Contractor shall obtain Engineer's prior approval before selecting such agency. The audit report & certificate from this agency shall be submitted by the Contractor to the Engineer.

N.B. Whichever Standard is selected for meeting the Fire Safety Criteria, then that standard shall be declared, and once accepted by the Engineer its requirements shall be met consistently throughout.

2.5.9 The procedures for Operation, Maintenance, Training and the Contractor's Quality Assurance manuals shall incorporate resolution of hazards so identified from this hazard analysis. Proper cross-referencing to the hazards and resolution measures shall be provided in all these aforementioned documents.

2.5.10 The following targets norms shall be employed for the Fault Tree Analysis. These norms are subject to review by the Engineer during the detailed design stage, and mutually agreed upon.

- (i) No single point failure shall lead to fatality.
- (ii) No combination of undetected failure and double point failures shall result in fatality.
- (iii) No combination of undetected failure and single point failure shall result in major injury.
- (iv) Under no conditions except for those specifically agreed by Engineer, the train shall be rendered immobilised in section

2.5.11 Source of all failure rates employed to be indicated in the Hazard Analysis.

2.5.12 All hazard analyses submitted to the Engineer are to be standardised by the Contractor such that format and forms employed by all Sub-Contractors are the same.

## 2.6 Fail Safe Design

2.6.1 All equipment and systems, including software, affecting train safety and the safety of train crew and passengers, and/or identified as being "vital", shall be designed according to the following principles (Couplers, door system, brakes, propulsion power removal, PEA shall be included, as a minimum.):



- (i) Only components having a high reliability and predictable failure modes and that have operated in similar service conditions to those in Mumbai shall be used.
- (ii) Components must be utilized in such a manner that ensures that a restrictive, rather than a permissive condition will result from a component failure. (For example: brakes will apply, rather than release; train will decelerate, rather than accelerate.)
- (iii) Circuits shall be designed such that when a normally energized electric circuit is interrupted or de-energized, it will cause the controlled function to assume its most restrictive condition. (Broken wires, damaged or dirty contacts, a relay failing to respond when energized, etc., shall not result in an unsafe condition.)
- (iv) System safety equipment design must be such that any single independent component or subsystem failure results in a restrictive condition. Failures that are not independent, those failures which, in turn, always cause others, must be considered in combination as a single failure and must not cause a permissive condition.

2.6.2 During the Design Review process, the Contractor shall submit analyses for Engineer's review and approval, which demonstrate compliance with these safety principles. These analyses shall address the following issues:

- (i) Circuit design
- (ii) Hardware design (Failure Modes, Effect and Criticality Analysis)
- (iii) Electrical interference
- (iv) Software errors
- (v) System failures

## 2.7 Reliability, Availability and Maintainability: General

- 2.7.1 Reliability, Availability and Maintainability (RAM) requirements and goals shall be developed in terms of Mean Distance Between Failures (MDBF), percentage Availability and Mean Time to Repair (MTTR). The Contractor shall perform RAM analysis up to the point of interface with other Contractor's systems.
- 2.7.2 The Contractor shall comply with the guidelines of IEC 60300-1, IEC 60300-2 and IEC 60571 for electronic equipment, and IEC 60300-3-5 in meeting the reliability, availability and maintainability requirements of equipment.
- 2.7.3 The Contractor shall submit Reliability, Availability and Maintainability Plan as specified in the Employer's Requirements: General Specification. The Contractor shall verify, after system design have been completed, that the reliability, availability and maintainability requirement will be met.
- 2.7.4 The Employer attaches the greatest importance to the attainment of the highest possible Reliability during service of all the equipment and systems supplied and installed under this contract. The design, manufacture, installation and commissioning of the equipment as also the training of the operating and maintenance staff shall be such as to ensure near Zero Failure performance in the initial stages and that the few defects and deficiencies that may be exposed during the Service Trial and the initial reliability growth period of one year are totally eliminated in the bulk supply. It shall also ensure that trains shall not be incapacitated under any condition unless there is inevitable mechanical failure.
- 2.7.5 The Contractor shall demonstrate by quantitative methods achievement of the specified levels of reliability for the train and specific individual items of equipment.
- 2.7.6 An evolving reliability model consisting of reliability block diagrams and probability of success equations shall be developed and submitted to the Engineer for acceptance. This model shall show the relationships required for system and equipment to operate successfully. The reliability block diagrams shall include all elements essential to the successful performance of the system and the interrelationships and interface of these elements.
- 2.7.7 Reliability apportionment and prediction analysis shall be in accordance with established techniques or standards, which will be submitted for acceptance by the Engineer. The analysis shall provide predictions for each major equipment and sub-system. Predictions shall be based on actual revenue service results for identical equipment operating under service conditions and duty cycles equivalent to Mumbai MRTS, or more severe. The analysis shall be carried out in parallel with the design of the train. The relevant apportionment and prediction figures shall be part of the design submission documents for the individual equipment, sub-system and system.
- 2.7.8 Reliability Apportionment and Prediction Report shall be completed prior to build commencing and



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reports shall be submitted at this stage for acceptance by the Engineer, who reserves the right to require the Contractor to carry out field data collection to verify the reliability model.

- 2.7.9 The design shall ensure that passenger deboarding cases in operational trains are bare minimum and avoided to the extent possible. Any deboarding incidence will invite penalty not exceeding Rs 15 lakh. Engineer's decision to impose the penalty shall be final.

## 2.8 Reliability Requirements

### 2.8.1 Definitions:

- (i) Relevant Failure: A relevant failure of an item is an independent failure which results in a loss of function of that item caused by any of the following:
- A fault in an equipment or sub-system while operating within its design and environmental specification limits;
  - Improper operation, maintenance, or testing of the item as a result of the Contractor supplied documentation.
  - Failures of transient nature including those with post investigation status as 'No fault found', shall be considered as relevant failure if in the opinion of the Engineer these are attributable to rolling stock. The decision of the Engineer shall be final.
- (ii) Non-relevant Failure: Any failure of an item not included in the definition of relevant failure, such as the following:
- A failure caused by malfunction of other equipment or subsystem that are not supplied by the Contractor;
  - A failure caused by human error, except as noted in Relevant Failure above;
  - A failure caused by accidents not associated with the normal operation of the item. Such as collision or striking a foreign object on the right of way;
  - A failure caused by operating the equipment or sub-system outside of design or environmental specification limits.
- (iii) Service Failure: Any relevant failure or combination of relevant failures during revenue service operations, simulated revenue operations, or during pre-departure equipment status checkouts to determine availability for revenue service, which results in one of the following:
- Non-availability of the train to start revenue service after successful completion of pre-departure checkout;
  - Withdrawal of the train from revenue services;
  - A delay equivalent to or exceeding 3 minutes from the Schedule / Time table as noted at the destination station for the one way trip.

The discretion of declaring a train as Not-available to start revenue service after successful completion of pre-departure checkout or withdrawing a train from revenue service on account of any relevant failure rests solely with the Engineer and shall be final. The train withdrawal scenerio is placed at Appendix TG and includes possible anticipated failure scenerios which can affect safety, punctuality and passenger comfort. The train withdrawal scenerio defined in Appendix TG shall be considered as a service failure irrespective of whether the Project Owner/Employer is able to withdraw the train or not due to its operational constraints. This list shall be further developed during DLP.

- (iv) Pattern Failure: Repeated occurrence of three or more relevant failures of the same replaceable part, item or equipment in same manner in identical or equivalent applications when they occur at a rate which is inconsistent with the predicted failure rate of the part, item or equipment.

The detailed methodology for identification of pattern failures shall be finalized during the design stage. The decision of the Engineer shall be final.

- (v) Mean Distance Between Failure (MDBF): The MDBF is the ratio of the total operating distance accumulated by the total available fleet of the trains to the total number of Service Failures.
- (vi) Mean Distance Between Component Failure (MDBCf): The MDBCf of a system is the ratio of the total operating distance accumulated by the total population of identical items in the available fleet of the trains to the total number of relevant failures occurring within the population identical items.

### 2.8.2 Reliability Targets:



- (i) Reliability shall be monitored for trains under reliability verification.
- (ii) The fleet average levels of MDBF, shall be calculated every month and shall be as specified in table 2.1, shall be achieved.

Table 2.1: Reliability Targets

Duration	Minimum fleet average MDBF
	6-Car fleet
After 6 months of start of revenue service plus stabilization period of 6 months as per para (iv) of this clause	100,000
After 12 months of start of revenue service plus stabilization period of 6 months as per para (iv) of this clause	125,000

- (iii) Wherever 'MDBF' is referred in this tender specifications, it shall be read as "AVERAGE MDBF", and shall be calculated as detailed in para (v) and (vii) as under.
- (iv) Any train shall be counted as available for reliability calculations only after a stabilization period of 6 months after putting the train into revenue service.
- (v) During the period of six (06) months to seventeen (17) months of induction of first train into revenue service, the AVERAGE MDBF of all the trains under reliability verification shall be calculated for the intervening period starting from the 06 months of the induction of first train into revenue service OR start of reliability verification of respective trains (whichever is later) and up to the month in which the MDBF is being calculated.
- (vi) The AVERAGE MDBF of 100,000 km or more, calculated as per para (v) above, shall be reached at the end of twelve (12) months of introduction of first train into revenue service.
- (vii) During the period including and beyond 18 months of induction of first train into revenue service, for those trains under reliability verification that have completed six(06) months under revenue service after entering reliability verification zone, the AVERAGE MDBF at any given month will be calculated for the period of preceding six (06) months. For all other trains under reliability verification, the AVERAGE MDBF shall be calculated for the intervening period starting from the month of start of reliability verification of respective trains and upto the month in which the MDBF is calculated subject to this period being equal to or less than six (06) months. For all such trains for which this intervening period exceeds 06 months, the period of only 06 months preceding the month in which MDBF is being calculated shall be taken.
- (viii) The AVERAGE MDBF of 125,000 km or more, calculated as per para (vii) above shall be reached at the end of 18 months of introduction of first train into revenue service (including stabilization period of 6 months as per para (iv) above). If this is not met, for each month after the 18<sup>th</sup> month where the MDBF calculated as per para (vii) above is less than the targeted MDBF of 125,000 km, the warranty (DLP) period shall be extended by one (01) month.
- (ix) When the targeted AVERAGE MDBF of 125,000 km is met, this shall be maintained until the end of warranty period. After the targeted MDBF of 125,000 km is met, if in a particular month, the AVERAGE MDBF as calculated as per para (vi) above is less than 125,000 km, one additional month shall be added to the warranty period.
- (x) The achieved level of MDBCf of major systems shall be as proposed by the Contractor in the bid.
- (xi) The Tenderer shall submit MDBCf of the major systems as listed in table 2.2 along with the bid.

Table 2.2 : MDBCf of major systems

S.N	System / Equipment	MDBCf (km)
(i)	Propulsion System	
	a) Pantograph	

	b) VCB and Earthing switch	
	c) Main Transformer	
	d) Power Converter – Inverter- 1. IGBTs & other Power components 2. Control Electronics	
	e) Traction Motor	
	f) Deleted	
(ii)	Auxiliary Supply System	
	a) Auxiliary Converter-Inverter	
	b) Battery Charger	
	c) Back-up Batteries	
(iii)	Air Supply system	
(iv)	Brake system Application & Release valves Other Valves & piping etc. Electronics	
(v)	Door System, components and Controls	
(vi)	HVAC System Refrigeration systems Control Electronics	
(vii)	Communication System PIS CCTV	
(viii)	Couplers and Draft Gear	
	a) Automatic couplers	
	b) Semi permanent couplers	
(ix)	Bogies	
	a) Drive gear and coupling	
	b) Primary suspension	
	c) Secondary suspension	
(x)	Lighting System	
(xi)	TCMS	

The achievement of MDBCf shall be demonstrated twelve months after the induction of first train in revenue service. The MDBCf values shall be calculated over a moving window of preceding six months till the MDBCf values are achieved and shall be maintained till the end of DLP.

- (xii) In addition, as a part of the Reliability Apportionment and Prediction report, the Contractor shall also submit the predicted MDBCf values pertaining to Service failures for the major systems/sub-systems and derive the predicted average MDBF for the fleet based on these predicted 'MDBCfs-Service Failures'.

## 2.9 Reliability Demonstration



- 2.9.1 The Contractor shall be required to establish a personal computer based Failure Reporting and Corrective Action (FRACAS) System to demonstrate compliance with specified train and equipment reliability. Any software or investigative/analytical tools required for the short term or long-term investigation/ analysis of the faults / trend shall be finalized during the design stage and complete set up for use by Project Owner/Engineer's personnel in warranty & post warranty period shall be provided in each involved depot. Software(s) shall be multiuser based. The reliability demonstration of each train shall start after six months of that train in revenue service and shall continue till the end of the defect liability period. Reliability of the trains and of the identified major systems shall be demonstrated on fleet basis.
- 2.9.2 The Employer shall collect and maintain data on every Service Failure along with the TCMS and sub system data indicating the probable failure. MDBF and MDBCF shall be calculated throughout the monitoring period. The Contractor shall collect all the relevant details from the Project Owner/Employer and submit monthly Reliability Demonstration Reports.
- 2.9.3 In case the Contractor is not able to achieve specified/provided reliability target of MDBF/MDBCF, the Contractor shall take necessary corrective measures either by way of change of design of the relevant equipment/ component or software modification.
- 2.9.4 The Contractor shall analyze and submit detail report to Engineer for each and every failure/defect of components of various equipment to determine the cause of failure and to propose corrective measures, which would be reviewed by the Engineer.
- 2.9.5 A record shall be maintained for each and every defect/failure in accordance with FRACAS as stated in Clause 2.9.1 to be submitted by the Contractor and approved by the Engineer.
- 2.9.6 Reliability shall be monitored during revenue service operation of the trains. The Contractor shall collect and collate data on each and every deficiency and failure observed by both himself and the Engineer, from handing over the first train to the end of the Defect Liability Period. Each and every failure, whether of component, sub-system or system, during this period shall be subject to a failure analysis to determine the cause of failure. The Contractor shall submit investigation reports for review of the Engineer.
- 2.9.7 Correction shall be made to components or subsystems that either fail to attain predicted reliability levels or show Pattern Failure, at no additional cost to the Project Owner/Employer.

## 2.10 Availability Requirements

2.10.1 Availability shall be assessed by the following measure:

$$\text{Percentage Availability} = 1 - \left\{ \frac{[DT(SC) + DT(OPM) + DT(CM)]}{\text{Total Time}} \right\} \times 100$$

Where:

- (i) Total Time is the time in hours in the assessment period multiplied by the number of trains commissioned under the Contract.
- (ii) DT (SC), or Down Time due to service checks, is the total down time in hours due to service checks summed over all the trains commissioned under the Contract during the assessment period.
- (iii) DT(OPM), or Down Time due to Other Preventive Maintenance, is the total down time in hours due to Preventive Maintenance other than service checks, summed over all sessions carried out on all trains commissioned under the Contract during the assessment period. The trains shall not be due for major overhauls at the time of demonstration and shall therefore be excluded from the assessment.
- (iv) DT (CM), or Down Time due to Corrective Maintenance, is the total down time in hours due to corrective maintenance, summed over all sessions carried out on the trains commissioned under the Contract during the assessment period. Any unreasonable delay in handing-over the train for repairs for reasons not attributable to contractor shall be excluded. Time spent on train integrity inspections after train reformations arising from corrective maintenance work shall be included.
- (v) The down times DT(SC) and DT(OPM) shall be counted starting from the moment when the train becomes unfit for service or work is physically started on a train, whichever is earlier, and shall end when the train is restored to service condition. If the train is withdrawn from revenue service specially for service checks or other preventive maintenance, time spent on withdrawing the train and sending back the train to revenue service, if any, shall also be included.
- (vi) Down time DT(CM) shall be counted starting from the moment when the train becomes unfit for service or work is physically started on a train, whichever is earlier, and shall end when the train is restored to service condition. If the train is sent to revenue service after the corrective maintenance,

the time spent on sending back the train to revenue service, if any, shall also be included.

- (vii) The down times DT (SC), DT (OPM) and DT (CM) shall also cover the full content of the maintenance work concerned, including safety precautions, inspections, servicing, replacement of equipment, defect detection and rectification, testing and restoration to service condition.

#### 2.10.2 Availability Target

The trains supplied shall achieve a minimum average availability of 95.0%.

#### 2.11 Availability Demonstration

- 2.11.1 The availability of trains shall generally be more than 90% during the period prior to 18 months from the start of revenue operation of the first train.

- 2.11.2 The average availability of the trains shall be assessed after 18 months from the start of revenue operation with the first train supplied under the contract, in a specified line and shall be as per ERTS 2.10.2. The total maintenance down times for all trains shall be collected by the Engineer on monthly basis, and the average availability during the preceding six months, shall be worked out from the above formula.

- 2.11.3 In the event that the availability target is not achieved, the determination of availability achievement in the preceding six month period shall be continued at monthly intervals until the target is achieved.

- 2.11.4 In the event that the availability target is not achieved, the Contractor shall, at his own expense, take whatever action is deemed necessary to meet the availability requirement.

- 2.11.5 In the event that average availability target is not achieved in any month after 18 months from start of revenue operation for the trains under reliability verification, the shortfall of trains on monthly basis (nos.) shall be included in the MDBF calculations i.e. the number of service failures in the corresponding month will be increased by the number of shortfall trains, for the purpose of MDBF calculations.

#### 2.12 Maintainability Requirements

- 2.12.1 Simplicity of maintenance, operation and emergency procedures, ease of repair of damaged cars and equipment, are most important. These together with ease of exterior and interior cleaning will be taken into account throughout the development of the design.

- 2.12.2 Particular attention shall be paid during the design of the cars to ensure that scheduled maintenance tasks are achieved in minimum time and using minimum manpower.

- 2.12.3 Those components, systems and assemblies which require routine maintenance, frequent attention or unit replacement, shall be easily accessible for in situ maintenance.

- 2.12.4 The Contractor shall develop a comprehensive maintenance programme for the trains.

- 2.12.5 The maintenance regime proposed for the train shall be developed during the design process. A Failure Mode Effect Analysis (FMEA) will be required, based on function and derived from the specification at conceptual design stage.

- 2.12.6 At pre-final design stage the Contractor will develop this FMEA to include required maintenance derived from each failure mode. Any other maintenance required for the train should be indicated at this stage. Methodology for the deriving maintenance activities including service checks, maintenance work instructions etc. based on failure modes shall be finalized at pre-final design stage only and the same shall be further reviewed by the Engineer during the DLP period.

- 2.12.7 The vehicle shall incorporate design, which reduces maintenance, substantially improving service intervals and component replacement. The design shall also minimize mean time to repair (MTTR) and costs throughout design life. MTTR is defined as ratio of Cumulative time for repair (including the access time expended during a time interval to total number of relevant failures.

- 2.12.8 The objective of the maintainability program including corrective and preventive maintenance shall provide for:

- (i) Enhancement of Vehicle availability.
- (ii) Minimisation of maintenance cost.
- (iii) Minimisation of vehicle down time.

- 2.12.9 During the Pre-Final design stage, the Contractor shall furnish a list of Least Replaceable Units (LRU's) for the equipment, Sub-system and Systems supplied, which should not take more than 30 minutes for replacement. Specific exceptions, if any, whose replacement is not achievable in 30



minutes, shall be indicated by the Tenderers in their offer. In order to achieve this requirement, quick release connections such as plugs and adaptor shall be provided between LRU's and the equipment.

2.12.10 The Tenderer shall submit the expected MTTR of the identified key systems as listed in table 2.3 along with the bid.

Table 2.3: MTTR of major systems

S.N	System / Equipment	MTTR (hours)
(i)	Propulsion System	
	a) Pantograph	
	b) VCB and Earthing switch	
	c) Main Transformer	
	d) Power Converter – Inverter	
	e) Traction Motor	
	f) Deleted	
(ii)	Auxiliary Supply System	
	a) Auxiliary Converter-Inverter	
	b) Battery Charger	
	c) Back-up Batteries	
(iii)	Air Supply and Friction Brake Equipment	
(iv)	Door System and Controls	
(v)	HVAC System & controls	
(vi)	Communication System	
(vii)	Couplers and Draft Gear	
	a) Automatic couplers	
	b) Semi permanent couplers	
(viii)	Bogies	
	a) Drive gear and coupling	
	b) Primary suspension	
	c) Secondary suspension	
(ix)	Lighting System	
(x)	TCMS ( hardware)	

2.12.11 During the final design stage, the Contractor shall submit periodicity, downtime and manpower requirements for the maintenance inspections and service checks considered necessary for maintaining the trains under normal operational conditions as per table 2.4. The service check sessions shall include all routine maintenance activities including inspections, cleaning, washing,



pest and rodent control etc. and shall not impact availability of trains for more than 1.5% averaged over annual basis.

Table 2.4 : Service checks

Session	Interval (Minimum)	Manpower and downtime requirements (Maximum)	
		Downtime	Expected Staff
Service Check 1			
Service Check 2, if any			
Service Check 3, if any			
.....			
Service Check n, if any			

2.12.12 The Contractor shall also submit periodicity, downtime and manpower requirements for the maintenance activities as listed in table 2.5, for maintaining the trains under normal operational conditions, during the design stage. In table 2.5, some of the values against identified activities are furnished. The Contractor shall either meet or provide better performance for these activities.

The periodicity of all overhaul activities of major items shall be synchronized with the below mentioned periodic and intermediate overhauling schedules.

Table 2.5 : Maintenance Activities

Session	Interval (Minimum)	Manpower and downtime requirements (Maximum)	
		Downtime	Expected staff
Periodic Overhaul	(8+ years)		
Intermediate Overhaul	(4+ years)	10 days	-
LRU Replacement	-	30 min	-
Corrective Maintenance operations that do not require car lifting	-	4 hours	-
Corrective Maintenance operations that require car lifting, excluding time required for shunting	-	6 hours	-

Note:

The Corrective Maintenance time as indicated above shall include defect identification, replacement of defective LRUs and restoration to service condition

2.12.13 In addition, the mid-life refurbishment period shall be specified along with complete details during design stage.

### 2.13 Maintainability Demonstration

2.13.1 The Contractor shall carry out tests to demonstrate that all maintainability predictions provided vide Clauses 2.12.10, 2.12.11 and 2.12.12 are met. All such tests shall be completed within twelve months after the commissioning of first train. In the event that any maintainability target is not achieved, the Contractor shall at his own expense take whatever action is deemed necessary to meet the maintainability targets.

2.13.2 The Contractor shall ensure that all the required information including the related Maintenance Work Instructions (MWI) etc. are submitted and available before the commissioning of the first train into revenue service or the commissioning last train set of the contracted quantity whichever is earlier to enable him to demonstrate the maintainability targets. The MWIs shall include details of the required materials and consumables, general tools, special tools and facilities in tabular form. All special tools and fixtures indicated in manuals shall be deemed to be included in the mandatory list of special tools under cost centre G of Annexure PBS to Price Bid Submission Sheet. Each



MWI shall be approved by the Engineer during design stage.

2.13.3 Maintenance and overhaul demonstration training of the sub-systems shall be organized within one year of the commissioning of the first train in the depot as per the approved schedule by the Engineer. Training shall include hand-on activity by the trainees. Separate spare sub-systems shall be supplied by the contractor within the quoted cost to demonstrate major overhauling. The training imparted shall include following:

- Detailed training notes (hard copy- two sets).
- Soft copy in a hard disk/ USB pen drive – for trainees (10 nos.) and additional 5 nos. for submission to the Engineer.

Training notes must include complete details of spare parts and details of tools & tackles required.

Computer based tutorials (CBT) package shall be part of the training material, which shall cover preventive maintenance and major/minor overhaul activities. CBT package shall have question bank (in sufficient numbers to choose from) for evaluation of the knowledge gained by the trainees.

Contractor shall note that the above said training shall be included in quoted cost and no additional amount would be payable. Price quoted in the cost center H do not include the above said training.

#### 2.14 Maintenance

2.14.1 The trains shall operate with minimum attention between the specified inspection periods, and shall, under the operating conditions specified, operate between overhaul periods without requiring replacement of components other than those on the agreed list of consumable parts to be proposed by the Contractor and accepted by the Engineer.

2.14.2 Special tools shall be avoided for maintenance. If unavoidable, they shall be supplied by the Contractor in requisite quantities in all the depots to meet the maintenance requirements.

2.14.3 Equipment design shall be modular to minimise down time following failures of equipment and components. Provision for mechanical handling devices shall be provided for any single piece of equipment weighing more than 35kg and all such items shall be identified as a part of Final Design Review (FDR). Equipment covers shall be provided with secure, visible, latching arrangements easily inspectable from the side of trains.

2.14.4 All underframe equipment which cannot be handled manually shall be configured such that it can be removed and replaced from track level using fork lift trucks or lift tables, with recognition being given to the confined environment of the pit and the rail level and underframe dimensions.

All underframe equipment shall be arranged such that it is capable of being removed and replaced without disturbing any other equipment.

All such items, that may be required to be accessed and worked upon (including operation) in the event of any unusual occurrence on line shall be such mounted that it shall be very easily accessible to the train operator from PF/track level.

2.14.5 If any equipment mounted above the ceiling requires the use of lifting equipment for its removal or refitting this shall be readily achievable without the risk of damage to the vehicle interior.

2.14.6 Removal and re-assembly of moving and wearing parts on bogies shall generally be carried out without the use of special tools.

2.14.7 Bogies shall be capable of being disconnected and reconnected to vehicle bodies with a minimum of operations. All connections must be easily and safely accessible to personnel located in pits or alongside the bogie at rail level. It shall be easy to inspect for correct reconnection, from alongside the bogie where possible.

Preference will be given to a design which permits release of the bogie to permit the raising of the car body, without the need for a pit in the Lifting Berth.

2.14.8 Each vehicle shall be capable of being lifted complete with bogies without the need to attach extra restraints or supports for the bogies or wheels.

2.14.9 Lubrication points shall have button head type grease nipples, and shall be easily accessible from rail level and shall, where possible, be grouped together.

2.14.10 On-vehicle test equipment shall be used on a vehicle to discriminate between a fault on the main equipment and a fault on the control electronic equipment.



- 2.14.11 Should the electronic equipment be found to be faulty, the equipment shall enable fault finding to be carried out at module level.
- 2.14.12 Off vehicle test equipment shall be used in the depot repair centre. This equipment shall allow fault finding down to the smallest replaceable item of equipment.
- 2.14.13 The unit shall have equipment cases and modules that are connected to the main vehicle wiring via connectors which are proven in equivalent service duties to achieve high reliability and are easily removable in the event of equipment replacement.
- 2.14.14 Equipment to which access will be required for faultfinding shall be conveniently located. A list of such equipment and their location shall be supplied.
- 2.14.15 The unit shall have provision for the isolation and where applicable, earthing of all electrical sub-systems to facilitate safe and systematic maintenance and fault diagnosis.
- 2.14.16 It shall be physically impossible for plug and socket connections and connections on safety-critical circuits to be mismatched.
- 2.14.17 The unit shall have standard test points on pneumatic systems. There shall be unrestricted access to facilitate checks during routine maintenance and fault diagnosis.
- 2.14.18 The abovementioned features shall be suitably reflected in the respective design documents, as applicable, during the design stage.

#### 2.15 **Electro-Magnetic Compatibility: General**

- 2.15.1 An EMC Control Plan shall be submitted by the Contractor as specified in the Employer's Requirements: General Specification for review by the Engineer.
- 2.15.2 The EMC Control Plan shall include measures to reduce conducted, induced and radiated emissions to acceptable levels as specified by the relevant international standards. The plan shall specify measures to increase immunity of the train and all its subsystems.
- 2.15.3 The plan shall specify basic protective measures proposed for all electrical and electronic subsystems and components and specific measures to be adopted for selected subsystems and components.
- 2.15.4 The plan shall analyse EMI and EMC impacts on the design of the train, all other train-borne equipment and track-side equipment as well as the general environment. Particular attention should also be paid to additional requirements in grounding bonding, shielding, filtering and cabling arrangements.
- 2.15.5 The Contractor shall ensure the compatibility of the system with the power supply as available in Mumbai Metro network duly considering other trains working in the system, fluctuations/interruptions in power supply and feed extensions. Contractor shall be fully responsible for correct functioning of their system and may make suitable measurements as deemed necessary.
- 2.15.6 The Contractor shall furnish complete harmonic emission/spectrum of the fleet/train/unit in both traction and regenerative modes at Panto level on simulation studies and validate its compliance through tests with the relevant EN/IEC standards or equivalent.
- 2.15.7 The Contractor shall also furnish the details of Power Quality for the regenerated energy including its harmonic analysis.

#### 2.16 **Electro-Magnetic Compatibility Requirements**

- 2.16.1 All components on the vehicle shall be designed and constructed to fulfil the requirements of EN 50121 and its parts. No degradation of performance shall be permissible during the tests.
- 2.16.2 The complete 3-car unit and 6-car trains shall meet the requirements of standard EN 50121-3-1.
- 2.16.3 The Contractor shall ensure that the return current limits specified by the respective Signaling and Train Control contractors are met (see Appendix TD).

#### 2.17 **Electro-Magnetic Compatibility Demonstrations**

- 2.17.1 Emission (radiated and conducted) and Immunity tests for all individual equipment provided on vehicles shall be performed under normal operating condition according to EN 50121-3-2.
- 2.17.2 The conducted emission test shall be performed under selected fault condition as specified in ERTS 3.22. The conducted emission test shall also satisfy special requirements of the ATO
- 2.17.3 The complete 3-car unit, 6-car and 8 car trains (if augmented) shall be tested to meet the



requirements of standard EN 50121-3-1.

2.17.4 The Contractor shall carry out joint testing with respective Signalling and Train Control Contractors as detailed in Appendix TD.

## 2.18 Noise and Vibration

### 2.18.1 General

- (i) The Contractor shall ensure that the cars and equipment are designed and built so that specified noise and vibration limits are not exceeded. Particular attention shall be given to the design of all equipment to minimise generation of noise and vibration. The design of the vehicle shall have adequate attenuation of airborne and structural-borne vibration along potential paths from the sources to passenger saloon and to wayside receptors.
- (ii) Exterior and individual systems and equipment noise measurements are to be made in accordance with ISO 3095, and interior noise measurements are to be made in accordance with ISO Standard 3381, except where otherwise specified. For evaluation, the noise level measurements shall be as per the specified criteria below.
- (iii) Ride quality vibration measurements shall be carried out in accordance with ISO 2631-1 (1997) and ISO 2631-4(2001).
- (iv) Deleted.
- (v) For all tests, the levels of all sounds or vibrations other than those being evaluated shall be not less than 10 dB below the levels of sound being evaluated, when measure with the same weighting network of (1/3) octave bands as that being used for the test.
- (vi) Wayside noise measurements shall be performed in an essentially free field environment with no nearby structures or reflective surfaces, which could influence the measurements, by more than 2dB, other than the standard track structure and the adjacent flat, clear ground. Squealing noise shall be measured at least on two sharp curves as directed by the Engineer.
- (vii) Interior noise criteria apply to measurement within an empty full fitted car. All noise level limits specified for car interior shall also apply to interior of gangway as far as practical. The noise level shall be measured at any point along the longitudinal centreline of the gangway and at a height of 1400mm above the gangway foot-plate.
- (viii) The pad stiffness used in DMRC ballast less track is generally 29MN/m and the same shall be used for design. The noise tests during running condition shall be done in the section after six months of train operation. The Tenderer may suggest change in pad stiffness if it can help in further reducing the noise level.
- (ix) All specified noise measurements shall be revalidated 6 months before the end of DLP on a representative train selected by the Engineer. In case of non-compliance, the Contractor shall take necessary action to correct the defect and revalidate.

Provision shall be made to use wheel noise dampers. The floor, door panels and ceiling shall essentially use honeycomb or better panels for noise reduction.

Contractor shall use noise simulation software tools to predict the noise compliance to specified values. Detail simulation report shall be submitted. The report shall be submitted at first stage of design approval. References of the projects where the simulation tool has been used and actual arrived values (Corresponding to the measurement procedure specified herein) shall be submitted. Copy of the software tool shall be submitted and Engineer's representative shall be trained for use of same.

### 2.18.2 Noise and Vibration Assurance Plan

- (i) The Contractor shall submit a Noise and Vibration Assurance Plan as specified in the Employer's Requirements: General Specification for review by the Engineer.
- (ii) The Noise and Vibration Assurance Plan shall include:
  - Expected total car noise levels, and sub-system noise levels for all equipment and systems including Noise Simulation Report as per 2.18.1(ix) above.
  - Expected vibration levels for equipment, system and measurement locations specified herein.
  - Expected dynamic characteristics of the primary and secondary suspension.
  - Details of proposed approach to determining noise and vibration of the cars.

- All codes and standards to be used during the design and verification of the cars.
  - Plan for noise and vibration design reviews.
  - Details of proposed sub-system testing to be carried out during the design and manufacture of the cars.
  - Details of proposed rake testing to demonstrate specification compliance.
- (iii) The Plan shall be updated at each Design Stage by the Contractor and be submitted to the Engineer for review. In the Design Reviews, the Contractor shall submit noise level and vibration prediction, calculations, design information, material property information, test results and other relevant data.
- 2.18.3 Interior Noise Level shall not be more than those specified in table 2.6.

Table 2.6 : Interior Noise Levels (  $L_{pAeq, 20sec}$  )

Location (Section)	Interior Noise Measurements in dBA		
	Stationary		Running (Elevated/At Grade)
	Elevated/ At Grade	Undergro und	75Kmph
All cars except in driving console	68	75	75
Driving console	68	72	70

Where:

- (i) During Stationary condition, the specified limits shall be met with all auxiliary equipment operating simultaneously at maximum capacity.
- (ii) For running conditions, the specified limits at specified speeds shall be met in elevated two track section including acceleration and deceleration) with all equipment operating simultaneously.
- (iii) All measurements to be made along the car centre-line 1400mm above the floor and not less than 600mm from the end of the vehicle.
- 2.18.4 Door Operation Noise produced by simultaneous operation of all saloon doors on one side of the car shall not exceed 75dBA during the sliding operation and 78 dBA for the locking/unlocking, measured on the fast meter scale. This should be measured at all points in the car 300 mm from the doors and 1000 mm above floor level.
- 2.18.5 Exterior Noise Levels for elevated (measured in two track section) and at-grade sections shall not be more than those specified in table 2.7.

Table 2.7 : Exterior Noise Levels(  $L_{pAeq, 20sec}$  )

Maximum Level of Exterior Noise in dBA	
Stationary	Running at 75Kmph
67	82

Where:

- (i) Exterior Noise level measurement to be done at a location 7.5 m horizontally from the track centreline on a horizontal plane passing through the axle centreline at any point along the length of the vehicle on either side.
- (ii) During Stationary condition, the specified limits shall be met with all auxiliary equipment operating simultaneously at maximum capacity.
- (iii) For running conditions, the specified limits shall be met for the entire speed range up to 75 kmph (including acceleration and deceleration) with all equipment operating simultaneously.
- 2.18.6 Noise levels obtained in underground tunnels and platforms shall be measured by the Contractor under the same conditions (as far as possible). These shall be submitted to the Engineer for reference purposes.
- 2.18.7 Vibration
- (i) The measured vibration on any portion of the car floor, walls, ceiling panels, stanchions, handholds



or seat frames shall not exceed the values specified below:

- 2.0 mm peak to peak vibration amplitude - frequency range from 1.4 Hz to 20 Hz.
- 0.8 mm per second peak vibration velocity - frequency range above 20 Hz.

(ii) All equipment, sub-assemblies and components shall be capable of withstanding shock and vibrations of the Rolling Stock satisfactorily such that they do not fail prematurely on this account earlier to the designed life. To establish this requirement, all of equipment, sub-assemblies and components shall be subjected to shock and vibration test to IEC 61373 or other relevant standards.

2.18.8 In addition to the Noise and Vibration Requirements mentioned in this ERTS, the cars and their equipment, sub-assemblies and components shall also comply with the requirements laid down in 'Guidelines for Noise and Vibrations for Metro Rail Transit Systems' issued by the Ministry of Railways, Govt. of India (Enclosed in Part-II of Tender Documents).

## 2.19 Fire Performance

### 2.19.1 General

- (i) Each train shall be designed to minimise the risk of a fire starting, as far as is practically possible.
- (ii) Materials used in the construction of each train shall be selected to reduce to the maximum extent practical the heat load, rate of heat release, propensity to ignite, rate of flame spread, smoke emission and toxicity of combustion gases.
- (iii) The train shall be designed to prevent fire propagation through the use of fire barriers in the floor, and in walls at the sides and ends and fire resistant equipment housings. Flammable materials shall be well contained with IP 65 protection. The vehicle floor shall provide a fire barrier of 30 minutes duration tested in accordance with EN45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions or better equivalent standard.

The design and the materials used in the cars shall conform to fire safety requirements of EN45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions or better international standards for similar metro operations, subject to the acceptance of the Engineer.

- (iv) The Contractor shall submit a plan to the Engineer for review which shall describe the process that will be used to systematically identify and eliminate fire hazards, to avoid the use of combustible materials whenever practical and to reduce to the extent practical the energy content and heat release rates of the combustible material that are used.
- (v) The plan shall include the Standards to be followed and the tests to be completed and shall be submitted for review by the Engineer.

### 2.19.2 Material Properties

Materials used in the cars shall meet the Flammability, Smoke Emission and Toxicity requirements of the chosen Specification. (See 2.5.8)

2.19.3 The contractor shall minimize the total fire load of potentially flammable materials on a vehicle as far as is practicable, but in any case, it shall not exceed the following:

- Above floor level : 22,000 MJ
- Below floor level : 26,000 MJ

Contractor shall furnish the relevant data, fire load calculations, certifications etc. of the items considered in fire load calculations separately for Above & Below the floor level. The calculations and validation shall conform to the standard adopted by the contractor for fire strategy.

## 2.20 Fire Detection System:

The fire detection system shall be able to detect any fire originating inside the cars. The focus is on protection of passengers and staff in rolling stock. The objective shall be to detect incipient fires in an early stage in order to warn Train Operator/OCC. A fire event shall be detected early during the development phase, the affected area shall be located exactly by identifying which sensor(s) is actuated and further system's actions shall be activated without any delay.

In case of fire, the entire air conditioning on the train must be switched off in order to prevent any transfer of smoke to other train parts. Ventilation shall be provided depending on whether the fire/smoke has been detected inside or outside of the passenger saloon area.

**2.20.1 System Design Requirements:**

The fire detection system shall consist of dual smoke and heat detectors (multi-sensors) in passenger area, Linear Heat Detectors (LHD) in technical areas (enclosures/cubicles) integrated with Fire Detection & Control Unit (FDCU). The FDCU shall interface with TCMS in a redundant manner. The interface of the system shall be suitably ensured with the overall system integration and GoA4 requirements.

All the major events (alarms, faults etc.) shall be recorded in TCMS and shall be retrievable on maintenance terminal for analysing any issue.

The system shall provide a dynamic two detector dependency (smoke and/or heat) in the passenger areas along with provision of drift compensation in order to decrease the risk of false, or unwanted alarm.

Alarm sounders/ Beacons shall be provided in train at a suitable location as well as in OCC.

The Contractor shall provide necessary diagnostic tools (softwares, hardwares etc.) in order to identify failures immediately.

The system should generally be SIL2 compliant. Any change in SIL level shall be subject to the hazard analysis and acceptance or otherwise of the same by the Engineer whose decision shall be final and binding.

The system shall be able to permit addition of 2 cars, Trailer(T) and Motor(M) cars in the existing 6-car train set configuration.

**2.20.2 Fire Detectors (Smoke & Heat Detectors) for passenger area:**

Minimum 4 no. of Smoke & Heat detectors (multi-sensors) shall be installed in passenger area of each car. The sensitivity of smoke detector has to fulfill the requirements of ARGE guidelines. The actuating temperature of heat detector shall be settable according to the international norms and standards.

**2.20.3 Linear Heat Detectors (LHD) for Enclosures/Cubicles (Electrical cabinets):**

A linear heat detector suitable for Rolling Stock applications shall be provided in the electrical cabinets. The linear heat detector is to be actuated in case of any fire/overheating in the electrical cabinets.

LHD shall also be provided in Underframe Electrical enclosures as mentioned in different chapters of this document. However, final decision on use of LHD/Heat detector in Underframe Electrical enclosures will be taken during design stage.

2.20.4 Provision for bypassing any faulty/malfunctioning detector may be required, for which final decision shall be taken during design stage.

2.20.5 The number of smoke/heat detectors, LHD and their exact location may vary and shall be finalized during design stage.

The fire detection system and layout of the detectors should be able to meet the criteria for the performance to be done as per the ARGE guidelines or any other applicable international standard.

**2.21 Life Cycle Cost**

2.21.1 The Contractor shall develop a life cycle cost plan in accordance with IEC 300-3-3 with an aim to minimize the overall life cycle cost whilst meeting the safety, quality, availability, maintainability and reliability requirement of this particular specification.

2.21.2 The LCC shall include, the capital cost, cost of operation (including energy consumption), maintenance (both material and labour), depreciation, refurbishment, inflation etc. Per unit energy consumption cost may be considered as INR 7.0.



**2.22 Deliverables**

2.22.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	2.18.1 (ix)	Noise Simulation software tools.	One set at Nominated depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



### 3. DESIGN AND PERFORMANCE REQUIREMENTS

#### 3.1 Scope

3.1.1 This chapter outlines the broad design and performance requirements of the Rolling Stock, details of track structure, power supply system, climatic and environmental conditions, and signalling & telecommunication systems

#### 3.2 Proven Design

3.2.1 The Contractor shall develop the design based on this specification and on sound proven and reliable engineering practices. The broad design details shall be submitted with technical data in the technical bid. Detailed calculations shall be submitted to the Engineer during the design process stage for review and approval.

#### 3.2.2 Sub-systems other than propulsion system

The Rolling Stock, including carbody, bogies, brake system components (valves etc.) all sub-systems, equipment and major components etc. (hereinafter referred as 'sub-systems') shall be state-of-art and of proven design. Proposed sub-systems shall have been in use and have established their satisfactory performance and reliability on at least three mass rapid transit systems in revenue service over a period of three years or more (in each MRTS) either outside the country of origin in three different countries or in an MRTS in India. Sub-systems/components used in existing rolling stock of an MRTS in India do not get automatically qualified for use unless specifically approved by the Engineer for this project. If required by the Engineer, Contractor shall provide certificate of satisfactory performance for a period of three years or more from the Metro operators. Where similar sub-systems of a different rating are already proven in service as per the above criteria then the design shall be based on such sub-systems.

All 'sub systems' shall be procured from the approved vendors and sourced from only such manufacturing units that have supplied the sub-systems that fulfill the proven design requirements as above. The contract envisages commencement of manufacturing only after completion of Pre-final design. Accordingly, the number of years in revenue service and operation for the above requirements shall be calculated as on the contracted Key Date No. 3.1 corresponding to 'Pre-Final Design Completion'.

In case the contractor proposes to use sub-system(s) that do not fulfill the above said criteria then the contractor shall furnish sufficient information to prove the basic soundness and reliability of the offered sub-system(s) for review of the Engineer. The Engineer's decision on contractor's proposal shall be final and binding.

#### 3.2.3 Propulsion System (Traction motor, Converter-Inverter and Auxiliary Converter-Inverter)

Propulsion systems manufacturer shall have at least 10 years experience of design and manufacturing of similar system. Proposed propulsion systems from the proposed manufacturing unit shall have been in use and have established their satisfactory performance and reliability for 5 years in minimum aggregate 500 cars comprising of both powered and non-powered cars, supplied either against minimum five (5) different contracts in the Metros (i.e. MRT, LRT, Sub-urban Railways and High Speed Railway) of minimum two (2) different countries outside his country of origin. If required by the Engineer, the Contractor shall provide certificate of satisfactory performance (for the supplies made from the proposed manufacturing unit) for a period of five years or more from the Metro operators. Where similar Propulsion systems of a different rating are already proven in service as per the above criteria, then the design shall be based on such systems.

Propulsion equipment shall be sourced from such manufacturing units that have supplied the equipment that fulfill the requirement of as specified above.

- (i) In case, the manufacturer of the proposed propulsion system is not a member of the Consortium/Joint venture and the contractor has indicated more than one manufacturer as the possible propulsion system supplier, final supplier out of the proposed manufacturers for the propulsion equipment shall be decided only after Employer's specific approval.
- (ii) In case the contractor proposes to use sub-system(s) that do not fulfill the above said criteria then the contractor shall furnish sufficient information to prove the basic soundness and reliability of the offered sub-system(s) for review of the Engineer. The Engineer's decision on contractor's proposal shall be final and binding.

3.2.4 Complete propulsion system comprising of converter–inverter, auxiliary converter-inverter including auxiliary supply modules and traction motor shall be from/of a single approved vendor. The Train Control and Management System (TCMS) shall either be from the qualified propulsion system



supplier (ref. ERTS 3.2.3) or from the carbody manufacturer/vehicle integrator provided the proposed TCMS is satisfactorily functioning in the metro cars as per "Attachment to Form Exp-2.1" of Part-I: Evaluation and Qualification criteria.

### 3.2.5 Vendor Approval

It shall be obligatory for the Contractor to obtain Notice of No Objection from the Engineer for the selection of the sub-contractor and vendors for all items of work, even if the name of the sub-contractor and vendor is named in the Contractor's Proposal and the works to be done including purchase of materials and equipment is in accordance with the Standards specified in the Contract. List of all major equipment/items of vendors shall be proposed by the Contractor during preliminary design (well before finalising the vendors), which will be reviewed by the Engineer and the Engineer may direct the contractor to include other items also for which vendor approval shall be mandatory.

The request for vendor approval shall be comprehensive with all relevant references and details establishing their compliance to the specified conditions. Along with the vendor approval proposal, a commitment from the proposed vendor shall also be submitted that in case of any future procurement action by Employer, they shall quote directly to Employer.

Contractor shall also ensure that the technical support from Sub-Contractors/Vendors of following major equipment/subsystems shall be made available through permanent positioning of Sub-Contractor's/Vendor's staff at Depots for meeting DLP obligations:

- (i) Propulsion system (including Converter-Inverter, Traction motors, Main transformer etc.)
- (ii) Auxiliary Power Supply system
- (iii) Brake and Pneumatic system
- (iv) Door
- (v) HVAC
- (vi) Bogies.

For sourcing the equipment from indigenous manufacturing facilities, following conditions shall be complied:

- (i) In case OEM wants to use manufacturing facilities in India (other than his own) for items for which the OEM has been approved, it shall enter into an agreement with such selected Indian equipment manufacturer and obtain prior approval from Employer. No change in composition, rating, type, model no., manufacturing process, quality standards, design, etc. and make of the components used in assemblies/sub-assemblies of such equipment as manufactured by the approved parent vendor shall be made without specific approval of the Engineer.
- (ii) In case the vendor uses his own facilities for indigenization after part supply of equipment from the approved manufacturing unit, no change in design, component type/make, quality standards, manufacture procedure, etc. shall be made without specific approval of the Engineer.
- (iii) In case OEM wishes to change/make/type specifications, etc. of any sub-components for supplies to be sourced from Indian facility, specific prior approval of the Engineer shall be obtained for changes made, model, specification, etc. Responsibility for obtaining such prior approval shall rest solely with the contractor. If the prior approval as per above is not obtained by the Contractor and supplies are sourced from the un-approved local Indian source then the Engineer at his sole discretion may direct the Contractor to replace equivalent no. of such items with supplies from approved sources free of cost.

Format for submitting the vendor approval request shall be given to the contractor during initial design stage and the same shall be followed throughout the contract.

### 3.2.6 Approval for manufacturing plant(s) for Rolling Stock

It shall be obligatory for the Contractor to obtain Notice of No Objection from the Engineer for manufacturing of tendered quantity of Rolling Stock in proposed plant(s). The plant(s) proposed by the Contractor shall have minimum five (5) years experience of manufacturing similar type of Rolling Stock as proposed for this tender. The Rolling Stock supplied from proposed plant(s) shall have been in satisfactory revenue operation for at least two (2) years.

In case Contractor proposes a new manufacturing plant(s) then the Contractor shall furnish sufficient information to prove the basic soundness and reliability of the proposal for review of the Engineer. The Engineer's decision on contractor's proposal shall be final and binding.

- 3.2.7 The overall performance of the Bidder (all members in case of JV/Consortium separately) shall be examined for all the ongoing Rolling Stock Works awarded by DMRC / any other Metro Organization (100% owned by Government) of value more than 40% of IFB cost of work and also for all the completed Rolling Stock Works awarded by DMRC / any other Metro Organisation (100% owned by Government) within last one year (from the last day of the previous month of Bid submission), of value more than 40% of IFB cost of work executed either individually or in a JV/Consortium.

The Bidder shall provide list of all such works in the prescribed Performa given in Appendix FB-18 of the Section-4: 'Form of Bid', at the time of Bid submission. The Bidder (all members in case of JV/Consortium separately) may either submit satisfactory performance certificate issued by the Client / Employer for the works or give an undertaking regarding satisfactory performance of the work with respect to completion of work/execution of work (ongoing works) failing which their Bid submission shall not be evaluated and the Bidder shall be considered non-responsive and non-compliant to the Bid conditions. In case of non-submission of either satisfactory performance certificate from Client / Employer or undertaking of satisfactory performance of any of the above work, the performance of such work shall be treated as unsatisfactory while evaluating the overall performance of Bidder in terms of Note (b) of Appendix FB-18. In case of performance certificate issued by the Client, same should not be older than three months (from the last day of the previous month of Bid submission for the ongoing works).

### 3.3 Basic Design Philosophy & Requirements

- 3.3.1 The design philosophy should meet the following criteria:

- (i) Application of state-of-the-art technology
  - (ii) Lightweight integral car body
  - (iii) Service proven design
  - (iv) Design life 35 years
  - (v) Crashworthiness
  - (vi) Minimum life cycle cost
  - (vii) Low maintenance and overhaul cost
  - (viii) Use of interchangeable, modular components.
  - (ix) Extensive and prominent labelling of parts and wires.
  - (x) Use of unique serial numbers for traceability of components
  - (xi) High reliability
  - (xii) Low energy consumption
  - (xiii) System safety
  - (xiv) Adequate redundancy in sub-systems
  - (xv) Fire, smoke detection and protection
  - (xvi) Use of fire retardant materials
  - (xvii) High passenger comfort including low noise level
  - (xviii) Environment friendly
  - (xix) Adherence to operational performance requirements
  - (xx) Safe passenger evacuation in emergency
  - (xxi) Maximum possible commonality of structure, components, equipment, and sub-systems amongst different cars.
  - (xxii) Maximum utilisation of indigenous materials and skills, subject to quality conformity to performance requirements and quality standards.
- 3.3.2 Adequate margin shall specially be built into the design particularly to take care of the higher ambient temperatures, high humidity, dusty and corrosive conditions, etc. prevailing in Mumbai area.
- 3.3.3 Specified temperature rise of equipment shall be calculated after taking into account at least 25% choking of air filters and/or radiator fins etc. unless specified otherwise against any equipment.



- 3.3.4 All the cars supplied under this contract shall have same equipment, layout and performance and modification/rectification/retrofitting as approved by Engineer shall be implemented fleet wise. Any change shall be specifically got approved from Engineer.
- 3.3.5 The circuit design, logics, software/hardware & interfaces proposed/agreed during design will be subjected to review and updating /rectification/modification etc. during DLP based on the operational, maintenance reliability or safety requirements and generally in accordance with the contractor's proposals. In specific cases, the Engineer may issue specific instructions in writing for undertaking the modifications to meet the above requirements. In such cases, the Engineer's instructions shall be implemented as instructed. The contractor shall abide by the Engineer's instructions without any additional cost.
- 3.3.6 It will be obligatory on part of contractor to ensure that the train design incorporates and provides all necessary equipment, systems or sub systems, facilities, interface etc., generally used/provided in recent operational UTO/GoA4 trains within quoted price, notwithstanding whether these have been specifically mentioned in the ERGS/ERTS or otherwise.  
In case of any necessary provision required to be incorporated in conformance to this clause, Contractor shall commit to incorporate the same into design at any stage for ensuring full compliance to this ERTS clause.
- 3.3.7 All the regulations as per "The persons with disabilities [equal opportunities, protection of rights and full participation] Act; 1995" shall be followed for the Rolling stock design, manufacture & features.

#### 3.4 Design Management and Control

- 3.4.1 In order to ensure that the requirements of this Technical Specification are met, the Contractor shall establish and maintain documented procedures using ISO 9001 to control and verify the design of the train and all its sub-systems. These procedures shall be subject to review and approval by the Engineer. Contractor shall have complete responsibility of correctness of design and its compliance with the specification.
- 3.4.2 The Contractor shall establish and maintain a systematic, documented, comprehensive, and verifiable system integration process throughout the execution of the Contract.

This process shall ensure that interfaces and interaction between cars, infrastructure, subsystems, software, and operating and maintenance requirements have been identified and engineered to function together as a system.

#### 3.5 System Integration Process

- 3.5.1 The Contractor shall systematically identify and formally document all design, manufacturing and operational interfaces between equipment within the train, and between the train and external systems, facilities, operations and the environment likely to affect or be affected by the train.
- 3.5.2 A mechanism and assigned project responsibility for interface management and control shall be provided, such that every identified interface has a defined resolution process that can be monitored.
- 3.5.3 The Contractor shall define methods to confirm compatibility between train consist sub-systems and carrying out integration tests at different stages of the design and interface management process to demonstrate that all sub-systems functions perform properly, both individually and as part of the complete train.
- 3.5.4 The Contractor shall ensure that performance, availability and safety requirements are addressed in the design process and that the reliability and maintainability of all sub-systems will enable the service performance to be met.

The system integration process shall be capable of audit by the Engineer.

#### 3.6 Interface Management

- 3.6.1 The Contractor shall submit to the Engineer for review an Interface Management Plan (IMP) and Detail Interface Documents, in accordance with the General Specification, which defines how the Contractor shall systematically identify and document technical interfaces.

#### 3.7 Design Submission Requirements

- 3.7.1 The Contractor shall perform his designs for the Contract in accordance with the General Specification. The Contractor shall submit to the Engineer for his review, relevant design information as identified under each stage. Such submissions shall incorporate the relevant international standards applicable and the copies of the applicable standards shall be submitted

along with the document.

The design submission requirements are detailed in the Employer's Requirements - General Specification.

### 3.8 Design Review

3.8.1 At appropriate stages in the design process, formal documented reviews of the design and related issues shall be planned and conducted. This shall be performed at fleet, train, car, system and subsystem levels, as appropriate, to verify and demonstrate:

- (i) Safety for manufacture, testing, operation and maintenance.
- (ii) Compliance with the relevant codes, specifications, the General Specification and this Technical Specification.
- (iii) Fitness for purpose, fulfilling the necessary operational functionality and performance.
- (iv) Integration and interfacing within the project and to external elements.

3.8.2 The Contractor shall submit for the Engineer's review a Design Review Schedule, in accordance with the General Specifications, which shall define the scope and timing of design reviews.

3.8.3 The Engineer reserves the right to attend any or all design reviews.

3.8.4 The Contractor shall ensure that participation in design reviews includes representatives of all functions, disciplines and entities concerned with the sub-systems and the stage being reviewed.

3.8.5 The Contractor shall at least 45 days prior to the date of each design review submit in-progress design documents of the elements to be addressed at the design review meeting.

3.8.6 The Contractor shall refer ERGS Chapter 5 for further details.

### 3.9 Employer's Design Audit

3.9.1 The Engineer will carry out design audits of the Contractor periodically throughout the Contract as deemed necessary for validation of the design.

Such design audits will generally cover issues related to performance, integration, co-ordination and operation and detailed design issues so far as they are considered necessary by the Engineer.

3.9.2 The Contractor shall provide all documentation and personnel participation reasonably requested by the Engineer to enable design audits to be carried out.

3.9.3 The Contractor shall within 15 days of the date of each design audit submit for review Design Audit Minutes detailing all issues raised during the audit, their resolution or ongoing design status and due date for resolution.

### 3.10 Climatic and Environmental Conditions

3.10.1 Extreme climatic conditions are given in Table 3.1

Table 3.1 : Climatic & Environmental Conditions

Description	Limiting Values
Maximum ambient temperature (See note 1 below)	36°C
Minimum temperature	14.3 °C
Humidity (See note 2 below)	≥95% RH
Rainfall	The annual precipitation is 2,078 mm with 34 % (709 mm) falling in the month of July.
Atmosphere during hot season	Extremely dusty including bird feathers
Maximum wind Speed	150 km/hr.



Vibration & Shocks	The sub-systems & their mounting arrangements shall be designed to withstand satisfactorily the vibration and shocks encountered in service as specified in IEC 61373 and IEC 60571.
SO <sub>2</sub> level in atmosphere	80 – 120 mg/m <sup>3</sup>
Suspended particulate matter in atmosphere	360 – 540 mg/m <sup>3</sup>

Note:

1. The temperature of the metal surfaces of the vehicles when exposed directly to the sun, for long periods of time, may be assumed to rise to 70°C.

2. Any moisture condensation shall not lead to any malfunction or failure.

### 3.11 Flood Proofing

3.11.1 The traction sub-systems mounted on the under-frame will be designed to permit propulsion of the train at 10 kmph through water up to a depth of 50mm above rail level. Traction sub-systems shall be made splash proof in accordance with International Standards.

### 3.12 Deleted.

### 3.13 Line Profile

3.13.1 The drawings showing the line profiles of all lines are enclosed.

- (i) Line 2: Dahisar(E) to Mandala
- (ii) Line 7: Andheri(E) to Dahisar(E)

3.13.2 All the above drawings (as referred in clauses 3.13.1) are to be found in Part-II, Supply Requirements. These drawings are currently under review. The permanent speed restrictions are also shown in the line profiles.

### 3.14 Track Structure Parameters

3.14.1 The Track Structure Parameters for At-grade, Elevated and Underground Corridors are set out in Table 3.2.

Table No 3.2: Track Structure Parameters

Description	Elevated and At-grade Corridor		Underground Corridor
	Ballasted	Ballast less (DFF)	Ballast less (DFF)
Track Laying Gauge	1435mm	1435mm	1435mm
Rail Type (Main Line and Depot)	60E1 (UIC 60) 880/HH	60E1 (UIC 60) 1080/HH	60E1 (UIC 60) 1080/HH
Rail Profile	UIC 861-3	UIC 861-3	UIC 861-3
Inclination Of Rail	1 in 20	1 in 20	1 in 20
Sleeper Spacing (Main Line)	600mm±10mm	600mm±10mm	700mm±10mm
Sleeper Spacing (Depot)	650mm±10mm	Not applicable	Not applicable
Ballast Cushion Depth (Main Line)	300mm	Not applicable	Not applicable
Ballast Cushion Depth (Depot)	250mm	Not applicable	Not applicable
Standard Rail Length	13m and 18m	18m	18m
Rail Panel Lengths	Longer than 200m	Longer than 200m	Longer than 200m

Minimum Radius of Curvature	200m- Underground 110m- Elevated 100m-Depot	200m- Underground 110m- Elevated 100m-Depot	200m- Underground 110m- Elevated 100m-Depot
Minimum Turn Out Radius (Main Line)	1 in 9 –300m radius 1 in 7 –190m radius	1 in 9 –300m radius 1 in 7 –190m radius	1 in 9 –300m radius 1 in 7 –190m radius
Minimum Turn Out (Depot)	1 in 7 –190m radius	1 in 7 –190m radius	1 in 7 –190m radius
Maximum Cant Permissible	110 mm	110mm	110mm
Maximum Cant Desirable	110 mm	110 mm	110 mm
Maximum Cant Deficiency Permissible	85 mm	85 mm	85 mm
Maximum Cant Deficiency Desirable	85 mm	85 mm	85 mm
Maximum Permissible Cant Gradient	1 in 440	1 in 440	1 in 440
Maximum Desirable Cant Gradient	1 in 720	1 in 720	1 in 720
Turn-out Speed : Turn-out (1 in 9) R-300	45 km/h	45 km/h	40 km/h
Turn-out Speed : Scissors (1 in 9) R-300	45 km/h	45 km/h	40 km/h
Turn-out Speed : In Depots (1 in 7) R-190	35 km/h	35 km/h	25 km/h
Turn-out Speed : Turn-out (1 in 7) R-190	35 km/h	35 km/h	25 km/h
Turn-out Speed : Turn-out (1 in 12) R-410	50 km/h	50 km/h	50 km/h
Turn-out Speed : Turn-out (1 in 12) R-410	50 km/h	50 km/h	50 km/h
Turn-out Speed : Turn-out (1 in 8.5) R-218	30 km/h	30 km/h	30 km/h
Turn-out Speed : Turn-out (1 in 8.5) R-218	30 km/h	30 km/h	30 km/h
Maximum Gradient Main Line	4%	4%	4%
Maximum Gradient Depot Connection	4%	4%	4%
Minimum vertical radius of curvature	1500m	1500m	1500m

### 3.15 Track Tolerances

3.15.1 The Track tolerances for At-grade, Elevated and Underground Corridors are set out in Table 3.3.

Table 3.3: Track Tolerances

Description	Ballasted	Ballastless (DFF)
Laying Tolerance of Vertical Alignment measured by 20m chord (Designed level)	+ 0 to -20mm	±3mm
Alignment (Laying) on 20m chord (Horiz)	±10mm	±2mm
Cross Level Laying Tolerance (Designed) (to be measured on every 3 mtr.)	±0 to -2mm	±2mm
Twist (Other than transition curve) (to be measured on every 3 mtr base)	Straight/curve-1mm/mtr	Straight/curve-1mm/mtr
Cross Level Difference (Maintenance)	± 5mm	±5mm



Gauge measured at a point 14mm below crown of rail (laying) (with respect to 1435 mm)	±2mm	±2mm
Sleeper to sleeper variation of gauge (laying)	2mm	1mm
Unevenness (Maintenance) (Base 3m)	±6mm	±6mm
Alignment (Maintenance) (Base 7.5m)	±5mm	±5mm
Gauge variation maintenance (sleeper to sleeper)	+4mm to - 2mm	+4mm to - 2mm
Gauge Widening (Laying ) – Tangent track ≥500m Radius, < 1000m – S.G. Track	+5mm	+5mm
Gauge Widening (Laying ) – Tangent track ≥1000m Radius – S.G. track	0mm	0mm
Gauge Widening (Laying ) – Tangent Track < 500m Radius – S.G. Track	+9mm	+9mm
Gauge (Maintenance) – Tangent track- S.G. track	±6mm	±6mm
Gauge (Maintenance) - ≥500m Radius, < 1000m – S.G. Track	±6mm over widened Gauge	±6mm over widened Gauge
Gauge (Maintenance) - <500m radius - S.G. Track	±6mm over widened Gauge	±6mm over widened Gauge
Gauge Face- Wear (measured 13 to 15 mm below rail top)	Straight- 6mm Curve- 8mm	Straight- 6mm Curve- 8mm

### 3.16 Platform Interface

3.16.1 The principal details of the Platform Interfaces are set out in Table 3.4.

Table 3.4: Platform Interfaces

Particulars		Measurements
Length of Platform ( 8 cars)		185 m
Width of Platform: Island type		8.0 to 12.0m
Side type		3.0 to 6.0m
Height above rail level	Ballasted Track	1080mm±5mm
	Ballastless Track (DFF)	1090mm±5mm
Floor height of the rolling stock		1130mm (max) 1100mm (min)
Distance between track centre and platform edge	At-Grade Corridor	1680 mm(max.) and 1670 mm (min.)
	Elevated Corridor	1680 mm(max.) and 1670 mm (min.)
	Underground Corridor	1670 mm (max.) and 1660 mm (min.)
Minimum horizontal curvature at platform		1000 m
Distance between track centre and platform edge on platforms at curve of 1000m	At-Grade Corridor	1700 mm(max.) and 1690 mm (min.)
	Elevated Corridor	1700 mm(max.) and 1690 mm (min.)
	Underground Corridor	1700 (max.) and 1690 (min.)

### 3.17 Current Collection System

3.17.1 The principal details of the Current Collection Systems are set out in Table 3.5.

Table 3.5: Current Collection System

System Particulars	For all sections and depots
Supply Voltage System	25kV AC single phase 50Hz

Type of OHE	a. Auto tensioned flexible catenary for elevated and at-grade sections. b. Rigid catenary for underground sections. c. Flexible catenary for depot.
Current Collection	Through Pantograph
Height of Contact Wire from rail level	a. 4800mm min. and 5500mm max. for elevated, at-grade and depot sections. b. 4318mm min. for underground sections.
Stagger	±200mm for Rigid Catenary; ±300mm for Flexible Catenary
Nominal voltage	25.0 kV AC
Minimum voltage	19.0 kV AC
Maximum voltage	27.5 kV AC
Instantaneous minimum voltage	17.5 kV AC
Occasional maximum voltage	31.0 kV AC
Voltage for guaranteed performance	22.5 kV AC
Variation in frequency	48 to 52 Hertz

### 3.18 Signalling System

- 3.18.1 Principal details of the Signalling and Train Control System are set out in Table 3.6. For details see Appendix TD.

Table 3.6: Signalling System

Item	Description
Train control system	CBTC based On board Continuous Automatic Train Control system (CATC) consisting of i) Automatic Train Protection ii) Automatic Train Operation (ATO) iii) Automatic Train Super-vision (ATS) iv) Attended/Unattended train operation (GoA2/GoA3/GoA4)
Train control mode	i) Automatic mode ii) Coded Manual modes iii) Restricted Manual mode iv) Run on Sight mode v) Cut-out mode vi) UTO vii) Standby

### 3.19 Telecommunication System

- 3.19.1 The communications links are required to be provided, for trains on all lines, as appropriate. For full details, and division of responsibilities, see Chapter 13 and Appendix TD.

### 3.20 Kinematic Envelope

- 3.20.1 Kinematic Envelope on tangent level track for At-grade, Elevated sections and Underground sections have been enclosed in Appendix TE. No part of any car shall infringe the respective Kinematic Envelope, under any circumstance whether empty or fully loaded, inflated or deflated air springs on main line at all train speeds and wind speed up to 100 kmph on At-grade & Elevated corridors.

On platform, the wind speed would be taken up to 70 Kmph & train speed up to 70 kmph for At-grade & Elevated corridors.

For underground corridor, there will be no wind speed for this purpose.

Track maintenance tolerances as per clause 3.15 above will be taken into account for this purpose. Maximum allowed flange wear will also be taken into account during calculations of all car displacements resulting from the simultaneous occurrence of all above conditions.

- 3.20.2 The Contractor shall furnish a static vehicle profile of the proposed cars to suit the Kinematic Envelope under all conditions indicated in clause 3.20.1. The car body dimensions shall be optimized and maximum space should be made available for the passengers.



3.20.3 The Tenderer shall confirm that the kinematic envelopes as given in Appendix TE shall be respected under all conditions indicated in Clause 3.20.1.

The contractor shall furnish detailed calculations, showing lateral and vertical shifts due to each factor indicated in Clause 3.20.1 separately.

3.20.4 Deleted.

3.20.5 The Contractor, during design stage, shall submit detailed calculation for minimum clearance between the carbody exterior and platform edge keeping in mind data regarding platform interface given in Table 3.4 (para 3.16) of ERTS. The calculations shall be made for tangent track and 1000 m curved track (inside and outside platform separately) at wind speed from 30 kmph up to 100 kmph in steps of 10 kmph & vehicle speed up to 90 kmph in steps of 10 kmph under inflated and deflated springs, worn out track & wheel & taking into account maximum dynamic sway on account of clearances etc.

The Contractor shall ensure that the Train shall enter and exit the platform at the maximum speed as achievable with the specified performance parameters up to a wind speed of 70kmph with worn out track and wheels. However, for new track without considering impact of wind, there shall be no restriction to pass the platform at maximum test speed.

3.20.6 The Tenderer shall ensure that the cars conform to the latest version of Schedule of Dimension which shall be made available during detail design stage.

### 3.21 Train Performance

#### 3.21.1 General

The following data shall be used for all normal and emergency performance requirements. The performance shall be guaranteed for traction supply voltage at 22.5 kV AC.

#### 3.21.2 Traction Electrical Supply Systems

The maximum and minimum voltages anticipated within the traction supply systems are set out in table 3.5 above.

#### 3.21.3 Car Weights

- (i) To minimise energy costs, great importance will be placed on achieving practical designs of minimum car weight whilst meeting specified structural and performance requirements.
- (ii) The total tare weights of a 3-Car unit (DM-T-M) shall not exceed 126 tonnes subject to gross axle load not exceeding 17 tonnes including IEC tolerances. The weight limits specified herein are the tare weight limit of the unit and gross axle load limit (tare plus AW3 load).
- (iii) The weight distribution shall be as defined in IEC 1133 - 1992.
- (iv) In case the actual weight of the train in tare condition exceeds the specified value as above, the Contractor shall be liable to pay the extra energy cost as a penalty, which shall be calculated on the basis of specified Specific Energy Consumption (SEC<sub>s</sub>) and Achieved Specific Energy Consumption (SEC<sub>A</sub>), whichever is higher on pro rata basis. The amount payable as penalty by the Contractor on account of increase in tare weight of the train shall be INR 15.0 Lacs/ ton per train with achieved SEC value of 47.5 Wh/GTKM (i.e. SEC<sub>s</sub>) or less. However, if achieved SEC is higher than 47.5 Wh/GTKM then the amount payable as penalty will be increased from INR 15.0 Lacs/ ton per train on pro rata basis.

Tenderers shall note that the measured value of tare weight of train for calculation of penalty shall be rounded up to next higher integer.

For example:

If the measured value of tare weight is 253.3 ton, the value of tare weight of the train would be considered as 254 ton.

In case the tare weight of the train exceeds the specified tare weight as above, the Contractor can improve the weight of the train by making suitable hardware modifications after obtaining approval of the Engineer. The payable amount on account of excess weight shall implemented on per train basis and shall be recovered from the payable amounts under respective cost centre 'B' / 'C' (as applicable) milestones.

The total amount payable as penalty by the Contractor will be the summation of penalty amount calculated on per train basis in all such trains in which tare weight exceeds the specified tare weight.

### 3.21.4 Passenger Capacity

The exact number of passenger seats and standees in DM car shall be worked based on the space released due to UTO (Unmanned Train Operations viz. GoA4) and performance calculations & equipment ratings shall be optimised based on final assessment of the passenger capacity. However, notwithstanding increased number of passengers as calculated during design, energy consumption/regeneration values committed by the contractor in the contract shall not be changed and shall be considered as base values for all further evaluations.

The approximate passenger capacity for each car (in UTO mode) under seating as well as standing mode shall be as under:

	Seating	Standing		Total (Seating + Standing)	
		Fully Loaded/Dense Crush loaded (AW3)	Crush Loading (AW2)	Fully Loaded/Dense Crush loaded (AW3)	Crush Loading (AW2)
'DM' Car	46	334	254	380	300
'T' Car	56 (each 'T' car)	324	244	380	300
'M' Car	56 (each 'M' car)	324	244	380	300
'First Class' DM Car	64	128	96	192	160
Total	334	1758	1326	2092	1660

#### Note:

- The seating capacity in each car and overall total passenger capacity in a 6-car train as mentioned in Table above is the minimum number to be achieved by the Contractor.
- However, with the approval of Engineer, the total passenger capacity of any individual car may vary subjected to para (i) above in a 6-car train.
- For AW3 loading condition, the number of passengers is estimated on the basis of standees at the rate of 8 persons per square meter.
- For AW2 loading condition, the number of passengers is estimated on the basis of standees at the rate of 6 persons per square meter.
- The weight of each passenger may be taken as 65 kg.

Performance requirements with AW2 loading as above have been specified in Table 3.7. Normal Train operation shall be with AW2 loading. TE/BE curves shall be adjusted suitably with the train loading as above and shall be suitably interfaced with signaling contractor. All load dependent type tests related with the train operations, run time, schedule speed etc. as decided by the Engineer, shall be done with AW2 loading as well. Based on the final design agreed by the Engineer, the contractor shall fine tune and validate the maximum number of loading of the train for which the operational performance can be met without diluting any of the design parameters.

### 3.21.5 Train Resistance:



The following train resistance formulae shall be used by the Tenderer to determine train resistance and guaranteed performance for all alignments, for At-grade, Elevated and the Underground sections alongwith the bid.

For At-grade and Elevated corridors:

$$R=14.01 + 0.264V + 0.00191V^2 \text{ N/tonne}$$

For Underground Corridor:

$$R=21.96+0.4222V+0.00876V^2 \text{ N/tonne}$$

Where, V= Speed in kmph

- The curve resistance may be taken as  $500/r$  kg per tonne, Where  $r$ = radius of curvature in metres.
- Starting resistance shall not be less than 5kg/ton.

The Tenderers shall use these formulae for all alignments for At-grade, Elevated corridors and Underground Corridor for giving performance details.

### 3.21.6 Wheel Diameters

Wheel diameter shall be taken as: -

- |       |            |        |
|-------|------------|--------|
| (i)   | New        | 860 mm |
| (ii)  | Half worn  | 820 mm |
| (iii) | Fully worn | 780 mm |

Train performance calculations shall be based on half worn wheels except where otherwise stated.

### 3.21.7 Command Response Time

- Command Response Time includes response to modulation within a mode (power, coast & brake) and transition from one mode to another, including emergency brake.
- Modulation within a mode shall be jerk limited. The command response time within a mode shall not exceed 300 ms.
- Mode change dead time for transition from one to adjacent mode (motoring to coast, coast to brake, brake to coast and coast to motoring) shall not exceed 500 ms, exclusive of jerk limiting.
- The command response time shall be measured from the time the change is initiated until the acceleration or deceleration transitions to 10 percent of the requested change.

The achieved command response time as per above shall be submitted during pre-final design stage.

## 3.22 Performance Requirements

- 3.22.1 The Rolling stock shall be designed for safe speed of 90 kmph and operational speed of and 80kmph respectively. In the interface with signaling contractor, the safe operational speed shall be considered as 90kmph, so that the maximum Target speed under ATP/ATO/UTO shall be 80kmph. Safe speed shall be considered as Rolling Stock design speed. The specified train performance shall also be achieved and validated during unattended train operations under GoA3/4 level of automation.

The performance requirements are given in Table 3.7 are with fully loaded train and tangent track

Table 3.7 Performance Requirements

Item		All Corridors
Safe speed	with inflated secondary suspension	90 kmph
	with deflated secondary suspension	80 kmph
Maximum operational speed	with inflated secondary suspension	80 kmph
	with deflated secondary suspension	70 kmph
Minimum Design Average Acceleration rate for fully loaded ( AW3) train on level tangent track shall be as under: 0 kmph to 40 kmph		1.0 m/s <sup>2</sup>

0 to 60 kmph 0 to 80 kmph	0.75 m/s <sup>2</sup> 0.40 m/s <sup>2</sup>
Minimum Operational Average Acceleration rate for AW2 loaded train on level tangent track shall be as under: 0 kmph to 35 kmph 0 to 60 kmph 0 to 80 kmph	1.20 m/s <sup>2</sup> 0.80 m/s <sup>2</sup> 0.45 m/s <sup>2</sup>
Average Service braking rate from 80kmph to standstill for fully loaded (AW3) train on level tangent track	1.0 m/s <sup>2</sup>
Average Service braking rate from 80kmph to standstill for AW2 train on level tangent track	1.1 m/s <sup>2</sup>
Average Emergency braking rate from 80kmph to 0 kmph for fully loaded train on level tangent track	1.3 m/s <sup>2</sup>
Jerk rate (Maximum)	0.75 m/s <sup>3</sup>
Annual running distance of one train (for design purpose)	150,000 km
Note : The specified average minimum acceleration shall be the finally achieved values inclusive of the specified jerk rate. Test procedure has been specified in Chapter 15	

Contractor shall advise the minimum energy consumption mode(s) under desired headways and schedule speeds as advised to them by the Employer during the design finalization stage. The software changes for such modes shall be advised with complete details to engineer and shall be implementable by the Engineer. Subsequent to the line trials of the trains, Engineer may review the jerk rate. The Contractor shall take suitable measure to fine tune the jerk rate accordingly without any extra cost.

3.22.2 Tenderers shall indicate the total runtime and the Guaranteed "Declared Schedule Speed (DSSP)" in kmph for a round trip from, Dahisar (E) Station to Mandala Station and back (Line-2) AND Andheri (E) Station to Dahisar (E) Station and back (Line-7), under following conditions:

- (i) Train loaded : AW3
- (ii) Mode of operation : ALL OUT MODE (ATP)
- (iii) Acceleration rates : Equal to or better than the rates specified in the performance table 3.7 above
- (iv) Average service brake rate from maximum speed to standstill shall be equal to or better than the specified brake rate in the performance table 3.7 above.
- (v) Round Trip from Dahisar East station to Mandala station i.e. the travel of a 6-car train set from Dahisar East to Mandala, Turnaround at Mandala then travel from Mandala to Dahisar and again Turnaround at Dahisar East so as to reach the same point from where the journey started.
- (vi) Dwell time at each station shall be 30 secs (including door opening and closing time)
- (vii) Total Turnaround time at both Dahisar East and Mandala stations including Dwell time at both the stations shall be 6 minutes (i.e. 3 minutes at each terminal station).
- (viii) Tenderers shall indicate total time for the round trip as round trip time i.e. RTT<sub>DSSP</sub>.
- (ix) Round trip time, dwell time and turnaround time for line 7 i.e. Andheri (E) Station to Dahisar (E) Station shall be considered in similar manner as specified in para (v) to (vii) above.

3.22.3 The Tenderers shall note that with AW2 loading the acceleration rates shall be suitably improved so as to achieve DSSP but with coasting of minimum 8% of the runtime (as defined in clause 3.22.2 above) i.e. the total time taken for a round trip minus the cumulative dwell time and reversal time.

Tenderers shall note that acceleration rates shall in any case be not less than the values specified in the performance table 3.7 above.



Tenderers shall furnish the considered acceleration rates for AW2 loading to achieve the above performance criteria.

3.22.4 Whenever the passenger loading is less than AW2, a load signal should be given to the traction system which should correspondingly reduce initial tractive effort and the constant power mode such that the running time between stations remain nearly the same i.e. the achieved schedule speed shall be same as the DSSP irrespective of the load on the train.

In this condition, the coasting time w.r.t. AW2 loading condition shall either increase or remain same and acceleration rate shall remain same from AW2 to AW0 loading conditions and shall be finalized during design stage.

3.22.5 The trains shall operate in the following modes:

(a) Normal (Coasting Mode) Mode:

- Accelerate the train using the designed and load weighed speed-TE characteristic of the rolling stock.
- Coast to achieve the Declared Schedule Speed(DSSP) which shall be the scheduled speed as per clause 3.22.2 above. The coasting time shall be equal to or more than 8% of the run time. Achieve rate of deceleration of not less than the values mentioned in Table 3.7 from at least 75 kmph running speed till 5 kmph with dynamic brake only and with blended brake from 5 kmph till the train comes to a stop. Full Service Brake requirements for speed range of 5 kmph to 75 kmph with load not exceeding AW2 shall be met with regeneration brakes only i.e. without any friction brake. The Regenerative braking power shall be constant from 80 kmph to 75 kmph. The regenerative power shall be used to the maximum extent possible. Deceleration for crush load shall be as specified in Table 3.7 above.
- The above steps should be taken in a manner such that scheduled speed is maximised and energy consumption is minimised. The DSSP are to be achieved with a dwell time as mentioned in ERTS 3.22.2 above at each station.

(b) All-out Mode:

This will mean maximum acceleration and deceleration with no coasting till maximum speed is achieved and thereafter speed is maintained within 5 kmph below than the maximum speed. During braking, maximum regenerative braking shall be utilised to achieve the specified retardation rate from top speed till train stops and the Jerk rate shall be limited within the specified limit.

(c) The Control system shall be such that the train will achieve the Declared Schedule Speed (DSSP) at all loading conditions subject to keeping the loading of traction system within the boundary limits of the design

(d) Normal mode will be used when trains are running in time and time table can be maintained. All-out mode will be used to make up time when trains are running late.

(e) When the train is in ATO/UTO mode, the train will get appropriate commands from Signalling system.

3.22.6 The Tenderer shall submit the data of the considered acceleration rates, average service brake rate, total Run Time, total Dwell and reversal time, Total time and Schedule speeds under different loading conditions and modes of operation enumerated in the table below:

Table No. 3.8

S. No.	Load	Mode of Operation	Acceleration Rate	Average Service Brake Rate 80 to 0 kmph	Total time (secs)			Schedule Speed (kmph)
					Run Time	Dwell & Reversal	Total	
1	AW3	ALL OUT MODE (ATP)	0 – 40 kmph =					
			0 – 60 kmph =					
			0 – 80 kmph =					
			0 – 35 kmph =					

2	AW2	ALL OUT MODE (ATP)	0 – 60 kmph =					
			0 – 80 kmph =					
3	AW0	ALL OUT MODE (ATP)	0 – 30 kmph =					
			0 – 60 kmph =					
			0 – 80 kmph =					
4	AW3	NORMAL MODE (ATP)	0 – 40 kmph =					
			0 – 60 kmph =					
			0 – 80 kmph =					
5	AW2	NORMAL MODE (ATP)	0 – 35 kmph =					
			0 – 60 kmph =					
			0 – 80 kmph =					
6	AW0	NORMAL MODE (ATP)	0 – 30 kmph =					
			0 – 60 kmph =					
			0 – 80 kmph =					

The Tenderer shall submit in their offer the speed-time, distance- time, line current –speed/time and tractive effort & Braking effort characteristic curves of a fully loaded (AW3), AW2 and AW0 loaded train under the specified voltage and wheel conditions in all out mode and normal mode, and also with the following details:

- (i) Round Trip Schedule speeds with 30s station stops for both the lines with:
  - a) all out mode; and
  - b) Coasting Mode excluding terminal station turnaround time with fully loaded train.
- (ii) Free run up to maximum speed and then Full service brake along with associated line current at each speed (traction component & auxiliary component to be indicated).
- (iii) Inter-station running time for each corridor, each way.
- (iv) Actual schedule speed with a dwell time of 30 seconds at each station.
- (v) Energy Consumption input at Pantograph during 'Non-Braking' (Traction & Coasting)
- (vi) Energy Consumption at input of SIV (Auxiliary Converter-Inverter) during 'Non-Braking'.
- (vii) Energy Consumption at Converter-Inverter unit during 'Non-Braking'.
- (viii) Energy Consumption input at Pantograph during 'Braking'.
- (ix) Energy exported during 'Braking' at Pantograph.
- (x) Energy Consumption at SIV (Auxiliary Converter-Inverter) from Line during 'Braking'.
- (xi) Regenerated Energy for input of SIV (Auxiliary Converter-Inverter) during 'Braking'.
- (xii) Regenerated Energy at Converter-Inverter input during 'Braking'.
- (xiii) Net energy consumption at pantograph.
- (xiv) RMS current loading.
- (xv) Line current plots.

Table No. 3.9

**Proforma for submission of simulation results**

**Line-2 (Dahisar East to Mandala)**

S. No.	Station/ Section	Run Time (Sec.)					Energy Consumption (kwh)				
		P	C	B	D	T (3 to 6)	P	C	B	D	T (8 to 11)
1	2	3	4	5	6	7	8	9	10	11	12
1	Dahisar (E) to Anand Nagar										
2	At Anand Nagar				30						
3	Anand Nagar to Rushi Sankul										











working, thermal rating should not be exceeded for continuous working throughout the day in each Line.

- 3.22.9 The Contractor shall handover one complete set of software(s) package and associated hardware employed by him for the above studies including assessment of energy conservation modes (ERTS 3.22.1) along with the requisite documentation, during design stage to the Engineer. The software shall simulate Run Time performance of the train under varied loads, route profiles, headway, inter-station distances, train resistance, Train formation and TE/BE characteristics, evaluation of energy conservation modes etc. The software shall not be restrictive to the above and shall be for general application with provision for the Engineer to select parameters. Nominated Engineer staff shall be fully trained and made fully conversant by the contractor for this purpose. The handed over set shall be fully functional during the contract period and post warranty period & shall require no inputs or facilities whatsoever from the Employer.

The supply of above software and its training shall be a prerequisite for completion of Final Design Review.

- 3.22.10 **The present tender is for procurement of a 6 car trainset. However, the design of the rolling stock would be such that if need be in future, it shall be possible to integrate a 2 car (T+M) unit and convert it into an 8 car trainset.**

The design of 6 car train shall take in to account future addition of one T and M car (if required) and the propulsion and other equipment ratings of the T and M car shall be optimally decided to form an 8 car train (with 62.5 % powering instead of 66.7 % powering). The design details and performance parameters of 8 car train shall be submitted by the Contractor during designed stage and got approved from the Engineer.

### 3.23 Emergency Operating Condition

- 3.23.1 The train shall in addition to the above be capable of meeting the following criteria without any damage to equipment

- (i) One serviceable fully loaded 6-Car train with one Motor car cut out shall be capable of pushing a fully loaded defective 6-Car train without parking brakes applied, on all Lines including a section of 4% gradient up to the next station. Thereafter, the healthy train shall, after all the passengers have been detrained at the station, continue to push the defective train up to the terminal station. There shall be no equipment damage or degradation, while maintaining safe operation. Train shall be also able to start and move on a up gradient of 4% on above condition including the conditions specified in clause 3.22.7.
- (ii) A 6-Car fully loaded train shall be capable of clearing the section, with the traction motors of one 3-Car unit cut out. The temperature rise of the traction motor and equipment shall be within rating of traction motor and other equipment in the above condition.

### 3.24 SPECIFIC ENERGY CONSUMPTION

Tenderers shall note that 'SPECIFIC ENERGY CONSUMPTION (SEC)' to be verified in Line-2 (Dahisar East to Mandala and back) under conditions detailed hereafter in this clause shall not exceed 47.5 Wh/GTKM, referred to as SEC<sub>s</sub>.

This Specific Energy Consumption shall be total of two components viz. SEC for a 6 car train (with HVAC switched off) i.e. 'SEC<sub>P</sub>' value and SEC of HVAC for a 6 car train i.e. 'SEC<sub>H</sub>' value. These two values shall be declared by the contractor (SEC<sub>P-declared</sub> + SEC<sub>H-declared</sub>) during pre final design stage and the same shall be validated as detailed in this clause. The total declared SEC value i.e. SEC<sub>declared</sub> for a 6 car train as declared by the contractor i.e. SEC<sub>P-declared</sub> + SEC<sub>H-declared</sub> shall not exceed the SEC<sub>s</sub> i.e. 47.5 Wh/GTKM as mentioned above.

Tenderers shall note that no adjustments of the 'SEC' values obtained during validation (SEC<sub>P-A</sub> (Achieved value of SEC<sub>P</sub>) and SEC<sub>H-A</sub> (Achieved value of SEC<sub>H</sub>)) will be permissible on account of any of the following:

- Increase in length of the network in Line 2 by up to 5% of the total length of the section between Dahisar East to Mandala including change in alignment.
- Increase in number of stations by 2 (two) stations in line-2 between Dahisar East station and Mandala station.



- iv) Efficiency curve of Main Transformer (auxiliary winding) during the dwell time and during run.

Contractor shall also take into account this  $D_{Aux}$  while declaring the value of  $SEC_{P-declared}$  during design stage.

Contractor shall note that detailed supporting data sheet for determination of  $D_{Aux}$  considering the above factors shall be submitted during design stage.

For calculation of the auxiliary load ( $D_{Aux}$ ), following shall be considered:

- Load of one main air compressor and one air dryer shall be considered.
- HVAC and associated control loads shall not be considered.
- The battery charger load shall be considered as only 25 % of the rated load.

Submission of above data shall be a prerequisite for accomplishment of milestone A11 (Pre-final design completion) as specified in cost center 'A' of Annexure PBS to Price Bid Submission Sheet and associated key date i.e. KD No. 3.1 as specified in Attachment to Appendix FB-1 to Form of Bid.

**A1.9** In support of the declared SEC value ' $SEC_{p-declared}$ ' during design stage, the Contractor shall submit the calculations, ratings and technical data sheet comprising of but not limited to:

- i) Complete simulation report (including run curve simulation, input data and assumptions made). The simulation report in xls format shall include the details of distance travelled, train speed, acceleration or deceleration achieved, electric effort (tractive or regenerative), mechanical effort and motion resistance at interval of 0.25 sec of run.
- ii) Traction motor voltage, current and DC link voltage at different speeds during powering and braking. Values shall be submitted in MS-Excel spread sheet for speed increment of one tenth of kmph.
- iii) TE, BE values for powering and regeneration shall be submitted in MS-Excel spread sheet for speed increment of one tenth of kmph.
- iv) Efficiency values of Main transformer, TM, CI, gear drive and auxiliary converter-inverter shall be submitted in MS-Excel spread sheet for speed increment of one tenth of kmph.

Note:

The above data including the detailed data [i.e.(i) to (iv)] of 0.25 sec interval for the complete run of round trip(A 1.1) shall be furnished in MS-Excel spread sheet. Submission of above data shall be a prerequisite for accomplishment of milestone A11 (Pre-final design completion) as specified in cost center 'A' of Annexure- PBS to Price Bid Submission Sheet and associated key date i.e. KD No. 3.1 as specified in attachment to Appendix-FB-1 to Form of Bid.

## **A2 SEC of HVAC for a 6 car train (Say ' $SEC_H$ ' Wh/GTKM)**

Specific Energy Consumption for functioning of HVACs of a 6 car train - (' $SEC_H$ ') as declared by the contractor i.e.  $SEC_{H-declared}$  shall be validated by conducting test on one car under following conditions in climatic chamber:

**A2.1** Round Trip time corresponding to DSSP ( $RTT_{DSSP}$ ), from Dahisar East station to Mandala station as mentioned in clause 3.22.2 shall be considered.

**A2.2** Dwell time for each intermediate station shall be 30 seconds including doors opening and closing. At terminal station, door opening and closing shall be considered twice, one on arrival and second before leaving the terminal.

**A2.3** The train shall be considered to be operated as explained in Clause 3.22.2 and the run time between stations shall be corresponding to DSSP as per Clause 3.22.2 and the same shall be considered for testing during validation.

**A2.4** Inside car temperature shall be maintained at 25°C. Contractor to note that the car inside temperature before opening of the saloon doors at each station shall be within 25° C.

**A2.5** Ambient (summer) conditions to be maintained outside the car. Ambient temperature, humidity and air speed of outside car shall be monitored as per EN 14750-2. Energy Consumption test shall be conducted at an air speed of 40 kmph.

**A2.6** Loading Condition: Heat load of AW2 numbers of persons as per EN 14750-1, throughout the round trip including the terminal turnaround time.

**A2.7** Doors opening and closing as per scheduled to and fro run on the route.

**A2.8** For terminal stations, 2 times opening as well as closing of doors shall be considered.

**A2.9** Contractor shall submit the efficiency value of Auxiliary Converter-Inverter and calculation sheets for:

- i) Cable losses between Auxiliary Converter-Inverter and HVAC with size and length of cables.
- ii) Efficiency curve of Auxiliary Converter-Inverter.
- iii) Cable loss between Auxiliary Converter-Inverter and main transformer.
- iv) Efficiency curves of Main Transformer during run, turnaround and during dwell time.

Submission of above data shall be a prerequisite for accomplishment of milestone A11 (Pre-final design completion) as specified in cost center 'A' of Annexure- PBS to Price Bid Submission Sheet and associated key date i.e. KD No. 3.1 as specified in attachment to Appendix-FB-1 to Form of Bid.

The energy measured on one car (M Car) in the climatic chamber will be multiplied by six (6) to determine the energy consumption by HVACs of a 6-car train in climatic chamber ( $SEC_{H-CC}$ ). Energy loss on account of items listed at A2.9(i) to A2.9(iv) shall then be added to the measured value above i.e.  $SEC_{H-CC}$  to determine the value of  $SEC_H$  i.e. ' $SEC_{H-A}$ '.

#### **B. Validation of Specific Energy Consumption:**

The validation of the declared values  $SEC_{P-declared}$  and  $SEC_{H-declared}$  shall be done as described below. However, the conclusion of validation shall be done in totality after the contractor has established the compliance of specified Specific Energy Consumption i.e.  $SEC_s$  value.

#### **B1 Validation of " $SEC_{P-declared}$ ":**

Validation of ' $SEC_{P-declared}$ ' under conditions noted above shall be carried out by the following method in two stages:

##### **B1.1 Validation on COMBINED TEST BED (Stage-1):**

**B1.1.1** The test protocol shall be prepared in detail and got approved from the Engineer before commencement of the test. In the "Combined Test Bed", all original relevant equipment such as Main Transformer, CI, Traction Motor and Auxiliary Converter-Inverter shall be considered. Type test results including efficiency curves at different loads for Main Transformer, Gear Case, CI and Auxiliary Converter-Inverter shall be considered for finalizing the test protocol.

For measurement, CT and PT of accuracy class 0.1 or better as in IEC 60044 shall be used. Energy meter of accuracy 0.15% or better shall be used.

**B1.1.2** The declared auxiliary load ( $D_{Aux}$ ) multiplied by the total round trip time (corresponding to DSSP as per clause 3.22.2) shall be added to the measured value while calculating specific energy consumption in the combined test bed set up. This value shall be the  $SEC_{P-A-Stage 1}$ .

##### **B1.2 Validation during Field Trial (Stage-2):**

**B1.2.1** The value of ' $SEC_{P-declared}$ ' shall also be validated in actual line run - round trip of a 6 car train set from "Dahisar East to Mandala" (under ATO/UTO mode of operation) as per conditions stated in para 3.24(A1) above. This measured value during field trial shall be the  $SEC_{P-A-Stage 2}$ .

**B1.3** Tenderers shall note that, to determine compliance of the total specified ' $SEC_s$ ' value, the



actual values determined on "Combined Test Bed" (B1.1) as well as the actual measured value in the line run test-round trip under ATO/UTO mode of operation (B1.2) would be considered.

**B1.4** To determine compliance, higher of the determined Specific Energy Consumption values on the combined test bed i.e.  $SEC_{P-A-Stage\ 1}$  and measured value in actual line test i.e.  $SEC_{P-A-Stage\ 2}$  shall prevail. The higher of the two values ( $SEC_{P-A-Stage\ 1}$  and  $SEC_{P-A-Stage\ 2}$ ) shall be considered as  $SEC_{P-A}$  (Achieved  $SEC_P$ ).

**B1.5** Deleted.

**B1.6** Combined Test Bed test for validation of ' $SEC_{P-declared}$ ' shall be conducted and concluded during the design stage and before dispatch of the prototype train set. Completion of Combined test bed validation shall be a pre-requisite for accomplishment of milestone for delivery of prototype train set and related key date i.e. KD No. 4.

## B2 Validation of " $SEC_{H-declared}$ ":

**B2.1** Before conducting Specific Energy Consumption test, the car level type test of the HVAC system should have been completed and the HVAC & Air duct system should have been found suitable.

**B2.2** Validation of ' $SEC_{H-declared}$ ' value shall be done in a climatic chamber as per conditions specified in 3.24 (A2).

**B2.3** To determine compliance with the declared specific energy consumption value for HVAC i.e. ' $SEC_{H-declared}$ ', the Contractor shall carry out test on a single car (M Car) in the climatic chamber.

**B2.4** Suitable necessary arrangements shall be made for providing almost evenly distributed sensible heat and humidity load inside the car with the help of thin film resistors, other heating devices and humidifiers for simulating the specified passenger heat loads and other heat loads. Heaters and humidifiers will be placed such that real life like situation is created.

**B2.5** Doors shall be opened and closed as detailed for a round trip and passenger load throughout the Round Trip (including terminal detention) shall be AW2.

**B2.6** Detailed instrumentation of the HVAC, car interior and exterior, and the climate chamber shall be done to monitor if the specifications and standards specified criteria are not getting violated at any time in during the test.

**B2.7** The Tenderers shall note that the ' $SEC_{H-declared}$ ' value validation test shall be carried out only after ensuring compliance of "Air Flow" and "Cooling Capacity test" exactly in line with the relevant standards and specifications of this tender.

**B2.8** Energy Consumption for HVACs for the car under test shall be multiplied by the number of cars in a train (i.e. 6 cars) to determine the Energy Consumption of HVACs for one train (" $SEC_H$ " Wh/GTKM).

**B2.9** Deleted.

**B2.10** Completion of Climatic Chamber test shall be a pre-requisite for accomplishment of milestone for delivery of prototype train set and related key date i.e. KD No.4.

**B2.11** In case, the round trip time i.e.  $RTT_{FT}$  during field trial for measurement of  $SEC_P$  is higher than the declared round trip time by the Tenderer during Bid submission (as per clause 3.22.2) i.e.  $RTT_{DSSP}$ , the adjustment (i.e. increase) in the achieved specific energy consumption of HVAC ( $SEC_{H-A}$ ) on pro-rata basis shall be made. For example, say the round trip time declared by the Tenderer during Bid submission is 50 minutes and during actual run, the round trip time was found to be 55 minutes.

$$RTT_{DSSP} = 50 \text{ minutes}$$

$$RTT_{FT} = 55 \text{ minutes}$$

Achieved value of  $SEC_H$  i.e.  $SEC_{H-A} = 17 \text{ Wh/GTKM}$  (say)

Then, the adjusted value of  $SEC_{H-A}$  shall be

$$SEC_{H-A-adjust} = (SEC_{H-A} / RTT_{DSSP}) \times RTT_{FT}$$

$$SEC_{H-A-adjust} = (17/50) \times 55 = 18.7 \text{ Wh/GTKM}$$

However, if the round trip time i.e.  $RTT_{FT}$  during field trial for measurement of  $SEC_P$  is lower than the declared round trip time by the Tenderer during Bid submission (as per clause 3.22.2) i.e.  $RTT_{DSSP}$ , no adjustment will be made in the achieved specific energy consumption of HVAC (i.e.  $SEC_{H-A}$ ) calculated as specified in para A2 above.

- B3** Based on the achieved value of  $SEC$  i.e.  $SEC_A$  [ $SEC_{P-A} + \{SEC_{H-A} \text{ or } SEC_{H-A-adjust} \text{ (as applicable)}\}$ ], after conclusion of the validation of  $SEC_S$ , if the contractor is unable to validate and establish compliance of total Specific Energy Consumption value i.e.  $SEC_S$  to the entire satisfaction of the Engineer, the Contractor shall carry out necessary modifications (hardware as well as software) in the Rolling stock to achieve the specified Specific Energy Consumption value ( $SEC_S$ ) and re-validate the same. In such cases, the revalidation will be again carried out after modifications as per clause 'B1' and 'B2' above including Air Flow Test & Cooling Capacity Test of HVACs.

Tenderers shall note that the achieved values i.e. ' $SEC_{P-A}$ ' and ' $SEC_{H-A}$ ' shall be considered up to one tenth of the unit with the one tenth component rounded up to the next value. For example:

- (i) If the achieved value of ' $SEC_P$ ' on combined test bed and/or during field trial is 26.11 Wh/GTKM, the value would be considered as 26.2 Wh/GTKM.
- (ii) If the achieved value of ' $SEC_H$ ' is 16.89 Wh/GTKM, then value would be considered as 16.9 Wh/GTKM.

For validation, the energy measured with external energy meter during field trials shall prevail.

Contractor shall submit calibration certificate for the energy meters used for measurement from an independent laboratory and such certificate shall not be more than 3 months old.

**B3.1 Measurements to be made for:**

S.No.	Description	Symbol
1.	Energy Consumption input at pantograph during 'Non-braking' (Traction & Coasting)	$E_{231}$
2.	Energy consumption at input of SIV (Auxiliary Converter-Inverter) during 'Non-braking'	$E_{221}$
3.	Energy consumption at Converter-Inverter unit during 'Non-braking'	$E_{211}$
4.	Energy consumption input at pantograph during 'Braking'	$E_{131}$
5.	Energy exported during 'Braking' at pantograph	$E_{132}$
6.	Energy Consumption at SIV (Auxiliary Converter-Inverter) from Line during 'Braking'	$E_{121}$
7.	Regenerated Energy for input of SIV (Auxiliary Converter-Inverter) during 'Braking'	$E_{122}$
8.	Regenerated Energy at Converter-Inverter input during 'Braking'	$E_{112}$

$$\text{Traction Energy Consumption} = E_{211} - E_{112}$$

$$\text{Auxiliary Energy Consumption} = E_{221} + E_{121} + E_{122}$$

$$\text{Total Input (E}_{IN}) = E_{231} + E_{131}$$

$$\text{Regeneration Output (E}_{OP}) = E_{132}$$



$$\text{Net Input} = E_{231} + E_{131} - E_{132}$$

Notations are explained below:

$E_{xyz}$

Where,

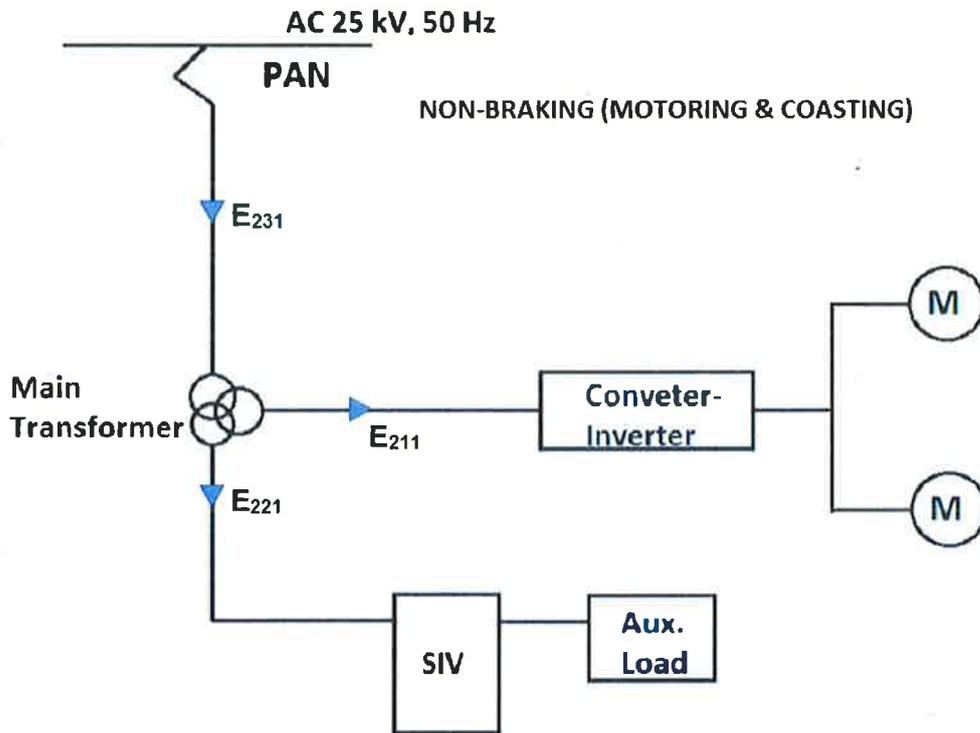
x specifies the mode of operation;

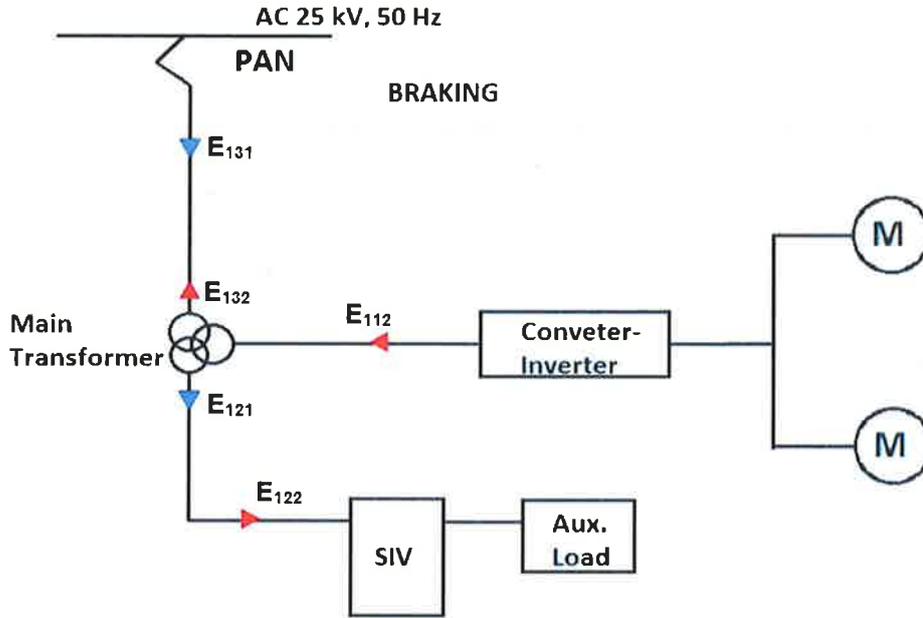
y specifies the equipment under consideration; and

z specifies whether the energy consumed from line or energy regenerated.

Subscript	Value	Description
x	1	Braking mode
	2	Non-Braking mode
y	1	Converter-Inverter unit
	2	SIV (Auxiliary Converter-Inverter)
	3	Pantograph
z	1	Energy consumed from line
	2	Energy regenerated

The above parameters may be visualized in the following diagrams for understanding only:





**C. Penalty in case of NON-COMPLIANCE by the Contractor:**

Contractor shall further note that in case the total achieved Specific Energy Consumption (SEC<sub>A</sub>) is higher than the specified Specific Energy Consumption (SEC<sub>s</sub>) value ( i.e. 47.5 Wh/GTKM), the penalty shall be imposed for the excess energy consumption.

The Penalty (P) shall be calculated as under:

**C1.1 Penalty for Non-Compliance of total Specific Energy Consumption:**

$$P = [(SEC_A - SEC_s)] / 1000 \times E \times W \times RTD$$

- 'P' : Calculated Penalty for non-compliance of "SEC<sub>s</sub>"
- 'SEC<sub>s</sub>' : Specified Specific Energy Consumption i.e. 47.5 Wh/GTKM
- 'SEC<sub>A</sub>' : Achieved total Specific Energy Consumption value [SEC<sub>P-A</sub> + {SEC<sub>H-A</sub> or SEC<sub>H-A-adjust</sub> (as applicable)}]
- SEC<sub>P-A</sub> : Achieved of SEC<sub>P</sub>
- SEC<sub>H-A</sub> : Achieved value of SEC<sub>H</sub>
- SEC<sub>H-A-adjust</sub> : Adjusted value of SEC<sub>H-A</sub> as per B2.11 above
- 'NRT' : Number of round trips considered per day (considered as '3')
- 'T' : Electricity Tariff per unit (considered as INR 7- per unit)
- 'NT' : Total number of trains (considered as '63' trains)
- 'L' : Life of the stock in years (considered as '35' years)
- 'D<sub>y</sub>' : No. of days in revenue operation in a year (considered as 345 days)
- 'E' : D<sub>y</sub> x NRT x L x T x NT = 345 x 3 x 35 x 7 x 63 = 15,975,225
- 'W' : Gross weight of train under loading condition of 114 passengers/car (296.5 T)
- 'RTD' : Round trip distance in line-2 i.e. 83.01 km



Contractor shall note that no 'bonus' is payable for achieving specific energy consumption figures better than specified ones.

For example, say the SEC values as achieved during validation are as follows:

Achieved value of  $SEC_P$  i.e.  $SEC_{P-A} = 29$  Wh/GTKM

AND

Achieved value of  $SEC_H$  i.e.  $SEC_{H-A} = 19.5$  Wh/GTKM

So, the total measured SEC i.e.  $SEC_A = SEC_{P-A} + SEC_{H-A}$

$SEC_A = 29 + 19.5 = 48.5$  Wh/GTKM

Therefore, the penalty amount for non-compliance of  $SEC_S$  shall be as follows:

$P = [(SEC_A - SEC_S)/1000] \times E \times W \times RTD$

$P = [(48.5 - 47.5)/1000] \times 15975225 \times 296.5 \times 83.01$

$P = \text{INR } 39,31,89,666$

**C1.2** In case, the contractor fails to establish the compliance of  $SEC_S$  during combined bed test and climatic chamber test, the penalty amount shall be deducted in equal proportions from the amount payable under the cost center 'B'/'C' (as applicable) for delivery of the trains.

**C1.3** In case, the contractor established the compliance during combined bed test and climatic chamber test but fails to establish the compliance of  $SEC_S$  during field trial, the penalty amount shall be deducted in equal proportions from the balance amounts payable to the contractor under any cost center and if still not recovered, it shall be adjusted by encasing the balance amounts from the Performance Bank Guarantee.

**C1.4** If the contractor fails to establish the compliance of  $SEC_S$  in both combined bed test & climatic chamber test as well as during field trials, then the final penalty amount shall be calculated based on the higher of the two SEC measurements (i.e. during combined bed test and field trial). However, the recovery of the penalty shall be made in accordance with clause C1.2 and C1.3 above.

**C1.5** The maximum amount of penalty calculated as per this clause 3.24 'C' shall however not exceed 10% of the total contract price.

### 3.25 Deliverables

3.25.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	3.22.9	One complete set of software(s) package and associated hardware as per Clause 3.22.9	One complete Set

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

**4.0 VEHICLE BODY****4.1 General**

- 4.1.1. Modern lightweight integrally structured rail passenger cars are required, using modular construction techniques for major components, such as roof, sides, floor and end modules.

Full details of the technique/technology employed for joining the modular elements of shells shall be furnished, along with details of quantity and service records of vehicles assembled using such techniques.

- 4.1.2 The cars shall be designed and constructed for a service life of at least 35 years of normal usage without major rebuilding, strengthening and repair.

- 4.1.3 Design of car body shall be such that sealants are not used as a primary protection for ingress of rain water.

The car body structure shall be constructed so that fixed or mobile jacks can be used to lift the car body, with or without bogies.

- 4.1.4 Additionally, arrangements shall be made to permit the use of portable jacks in a restricted space to re-rail a car after derailment.

- 4.1.5 Full details shall be provided of the arrangements made to provide seating for jacks and body stands, both for normal and emergency applications.

- 4.1.6 Engineer's approval shall be taken for finalizing carbody shape and aesthetics.

- 4.1.7 Employer envisages supply of trains with unpainted stainless steel car body against this tender.

**4.2 Mock-ups - General**

- 4.2.1 The Contractor shall make available for review at specified locations, the mock-ups specified in Appendix TB. The Contractor may combine various aspects into one or several mock-ups, so long as a clear demonstration is possible of each of the aspects or functions set down in the Appendix. Complete car body as mock-up will be preferred. Digital model alone shall not be acceptable except for the roof layout. The mock-up shall be manufactured with non-inflammable items only so that this can be placed safely within the closed space for training or public view.

- 4.2.2 The mock-ups shall demonstrate the proposed design and design options, and shall progressively increase in detail and level of finish as the design progresses. The mock-ups shall be constructed at the Contractor's facilities. The Contractor shall allow a minimum of two formal reviews by the Employer (4 members). Employer shall depute a team of Engineers (around four) to Contractor's/Sub Contractor's/Vendor's premises for a minimum of two formal reviews. Total expenditure including air tickets as per entitlement and boarding charges shall be borne by the contractor. In such case, Contractor shall provide office facilities at their own cost.

- 4.2.3 After each review, the Contractor shall incorporate the Engineer's comments into the mock-ups prior to the following scheduled review. The mock-ups shall be updated to include prototype/pre-production examples of major equipment such as seats, doors, driving console, etc.

- 4.2.4 The final mock-up shall be maintained at the Contractor's premises till the first train is introduced in revenue service. Subsequently, at the sole discretion and instructions of the Engineer, the completed mock-up shall be delivered to the Employer at site. In case, mock up is not required by the Employer at site then the payable amount under milestone no. A15 will be reduced by 10%.

- 4.2.5 After the final review of the mock-up, and within two months of receipt of prototype, the Contractor shall prepare and handover to the Engineer, 20 numbers miniature approximately 1:50 size true models of the DM-car (non-working), with pedestal and casings. Sample of the model shall be got approved from the Engineer.

- 4.2.6 The Contractor shall prepare and handover to the Engineer, one true model of stainless steel (non-working) of a 6 car train DM-T-M-M-T-DM, approximately 1:20 size, duly equipped with representative track, OCS, interior-exterior furnishings, internal illumination, headlight, marker light and flasher light, display boards, pedestal and casings. All lights in the model shall be functional. Suitable stand (duly approved by the Engineer) shall be provided with the model. The same shall be delivered along with the delivery of the prototype train. Sample of the model shall be got approved from the Engineer.

**4.3 Static Vehicle Profile**

- 4.3.1 The Tenderer shall design the cars duly considering the Kinematic Envelope provided by the Employer.
- 4.3.2 The notional leading particulars of the driving motor car trailer car and motor car are set out in Table 4.1.

Table 4.1: Principal Notional Vehicle Dimensions

Description	Dimension	
Gauge	1,435 mm	
Maximum length over Body (including end-fairings)	DM car	22,010 mm
	T and M cars	22,010 mm
Maximum Length over couplers for all cars	23,000 mm	
Maximum Width over Body	3,200 mm	
Minimum Passenger Saloon Headroom	2,050 mm	
Locked down pantograph height for 25kV AC cars from rail level at Car Centre Line	4,048 mm	
Maximum Floor height above rail level of any unloaded vehicle	1,130 mm	
Minimum Floor height above rail level of fully loaded vehicle	1,100 mm	
Maximum height of coupler above rail level for unloaded vehicle	815 mm	
Minimum height of coupler above rail level for fully loaded vehicle	740 mm	
Bogie wheel base	Maximum	2400mm
	Minimum	2200 mm
Distance between bogie centres	Maximum	15,100 mm
	Minimum	14,400 mm
Wheel diameter	New	860 mm
	Fully worn	780 mm
Maximum axle load	17 Tonne (including all tolerances as per IEC 1133-1992)	

- 4.3.3 The addition of two cars as mentioned in clause 1.1.5 shall not increase the average axle load not exceeding 17 Tonne and keeping weight as per IEC-1133-1992.
- 4.3.4 Common body shell structure shall be adopted for all types of car.
- 4.3.5 The design shall ensure that the vehicle remains within the Kinematic Envelope under all conditions (both in tunnel as well as on at-grade and via-duct). The carbody shall be optimized to maximize use of permissible Kinematic envelope.
- 4.4 Materials**
- 4.4.1 The car body shall be constructed of austenitic stainless steel of grade SUS301L to JIS G4305 or equivalent international standard. The Contractor shall bring to the notice and take prior approval of the Engineer, if any of the components of the car body is intended to be of different material. Intermix of Aluminum & Stainless Steel shall not be permitted.
- 4.4.2 Throughout the design life of 35 years, the car body material shall not corrode or be etched by the environmental conditions (See also Clause 3.10.1) that exist in Mumbai and surrounding area and its tunnels to the extent that the original appearance of the car cannot be restored by normal washing. In particular, the cars shall withstand contamination from water dripping within the tunnel environment. During the design life, there shall never be serious mechanical failures of bearings, gears, motor or wheel set which may lead to unsafe conditions/ blocking of operational line during service unless due to neglect of maintenance by employer, accident or misuse. There shall be no structural failure or fatigue cracking of carbody, bogies or underframe load carrying brackets or fixtures during the design life.
- 4.4.3 The exterior appearance of the car body with stainless steel shall be smooth (not corrugated) unpainted metal without the use of filler or other similar material, such that the maximum variation from the required car profile, over any one meter length, shall not exceed 1.5 mm. Any fluting, if offered, shall be shown to have advantages, and shall be subject to review by the Engineer. The roof, excluding the cant rail, may be either corrugated or smooth.
- 4.4.4 Complete coach including underframe of the coach shall be of Austenitic stainless steel except end

underframe / body bolster which may be of Light Alloy High Tensile (LAHT) steel. Preventive measures to prevent galvanic corrosion at dissimilar metal contacts to be ensured.

4.4.5 Deleted.

4.4.6 The finish of the texture shall be subject to approval by the Engineer whether applied by machine or hand. The employer shall approve the finish and approved finish texture shall conform to ASTM A480 or relevant standard: Finish of stainless steel sheets and strip.

4.4.7 In the case of stainless steel cladding materials below 6mm in thickness, the side and end wall sections and under frame shall be manufactured from rolled sections, folded or pressed plates, or plain sheets.

4.4.8 All welds including spots welds marks shall be passivated with acceptable procedure to protect against any visible rusting/chemical deposits/blackening etc.

4.4.9 Non-stainless steel surfaces below the floor of the carbody shall be primed with epoxy coating and then finish painted with two coats of an approved polyurethane paint.

#### 4.5 Car Weight and Passenger Capacity

4.5.1 The tare weight of the cars, passenger capacity and weight of passengers are detailed in Chapter 3 (clause no- 3.21.3 and 3.21.4).

#### 4.6 Car Body Strength

4.6.1 The mechanical strength of the car body structure shall comply with the requirements of EN 12663 Category PIII. The Contractor shall carry out stress analysis of car body as well as for important structural components which affect safety and availability using the finite element method. However, the strength of the car body shall be decided during design stage by meeting EN 15227 & EN 12663 with exceptional passenger load of 10 passenger/m<sup>2</sup>.

4.6.2 The vehicle shall withstand an evenly distributed downward vertical load equal to 1.1 x the weight of the vehicle complete with all its equipment and supplies, but no passengers, with the body supported at the lifting points provided by the Contractor close to the ends of the body bolsters in the under frame.

4.6.3 For the purpose of strength analysis, the number of passengers seated shall be taken as one per seat and standing as ten per square meter and the weight of each passenger shall be taken as 65kg.

4.6.4 For a welded construction, the camber on coach body under loaded condition with 10 persons/m<sup>2</sup> shall be such that the structure shall not sag below the horizontal plane throughout the vehicle's 35 years life. However, for shells fabricated with modular elements, the coach shall be built with a suitable camber under tare condition. It shall be ensured that the downward deflection of the coach in fully loaded condition (with 10 person/m<sup>2</sup>) shall be within the permitted deflection throughout the service life of thirty five years to ensure proper operation of doors under all loading conditions. Detailed calculations shall be submitted by the contractor for the expected deflection so as to confirm that the deflection is within permissible limits under all conditions throughout the life of the coach. Tests for stresses etc. as well as other tests as per relevant standard for the method of construction deployed shall be carried out under specified loads.

4.6.5 Vertical deflection of the car body structure, up to the fully laden condition, shall not hinder the normal operation of the passenger doors.

4.6.6 The car body, and any equipment mounted on, beneath or within it shall be designed to withstand the fatigue loads that the car body structure will encounter over a period of 35 years in service, in accordance with the criteria described herein. The fatigue life assessment of body structure shall be carried out using recognised techniques and shall be submitted by the Contractor for review by the Engineer.

4.6.7 Suitable acoustic insulation shall be provided on the body side and roof sheet to minimise the effect of reflected noise into the saloon. The carbody shall be designed to have high thermal insulation to reduce the heat loss and heat transfer coefficient (K value) of the carbody excluding glazing/windows shall be kept within 1.6W/(mK). The calorific value of the insulation material used as well as the material used for fixing the insulation shall be bare minimum.

#### 4.7 Equipment and Equipment Mounting

4.7.1 All equipment, mountings and fasteners of components shall withstand the forces and impacts as specified in UIC 566/EN 12663 without any part of the equipment becoming detached, and without



any permanent deformation to the car-body.

- 4.7.2 The roof structure shall be designed to support the HVAC equipment, pantographs, VCB, surge arrestor, ducts, conduit, lighting fixtures, headlining, stanchions and other equipment, and shall, in addition, have sufficient strength to support, without permanent deformation, concentrated loads of 1000N, applied by personnel working on the roof at increments of 750mm apart. The minimum thickness of roof sheet shall not be less than 1.0mm.

There have been cases of roof getting damaged due to stray wires dropping on the live OHE and flashing through roof sheet. Details can be seen at Clause 4.16.1. In order to avoid puncturing of roof sheet, minimum thickness of roof sheet shall not be less than 1.0 mm.

- 4.7.3 The Contractor shall carry out a stress analysis of the car body (including torsion mode) as well as for important structural components that affect safety or availability, using the Finite Element Method. The analysis shall demonstrate that all static and fatigue strength requirements of the car body and equipment mounting are met.
- 4.7.4 Calculations of the moments of inertia of the car body about its longitudinal and transverse axes shall be furnished, together with those of the car body bending frequency.

#### 4.8 Crashworthiness

- 4.8.1 The car structure and its supplemental energy absorption devices shall be designed to minimize accelerations transmitted to passengers, by absorbing collision energy, whilst not permitting one vehicle to over-ride another, nor to telescope one into another. The overall design shall conform to EN 15227. Energy absorbing tubes (anti climber) shall also be provided in between the cars to reduce the risk of overriding within the vehicle after coupler failure.

EN 15227 states that Crashworthiness validation shall be done at 25 kmph for identical metro train units, which shall be assumed to be equal to train colliding a rigid wall with 12.5 kmph. Contractor shall analyse such scenarios during design stage and safety at survival space and structural integrity of the occupied areas shall be maintained in this scenario.

The car structure design shall meet the criteria laid down in EN15227 at 25kmph collision.

- 4.8.2 The car body design shall be suitable for a six-car train and shall be such that it is capable of absorbing collision energy in a manner so as to localize structural deformation at low energy levels.
- 4.8.3 A suitable proven energy absorption feature with associated collapse features shall be incorporated into the coupler draft gear. The coupler shall sustain no permanent damage when a fully loaded six-car train collides with an impact speed up to 10 kmph with another stationary fully loaded six-car train with braked (maximum parking brake) and un-braked conditions.
- 4.8.4 At high energy levels it shall ensure that collision energy is absorbed by progressive deformation of the Coupler structure, Anti Climber at driving car end as well as in between the cars and the vehicle end structure, thereby protecting the passengers and passenger area in the car. There shall be least deformation between the body bolsters.
- 4.8.5 Of particular concern is the driving car front structure, which is required to protect the train operator, and vital control and communications equipment in the event of a collision. The Front part of the driving car is to be used as an emergency escape route from driving car to track

The Tenderer shall submit his proposal for the structural arrangement of the driving car front and sides, and the manner in which members tie-in with the under frame and roof structure.

- 4.8.6 The Tenderer shall submit predicted values for the following in respect of fully loaded cars. The Contractor shall submit a detailed technical proposal and analysis to specify the following in respect of the fully loaded 6 car train colliding with another fully loaded braked and unbraked stationary 6 car train:
- (i) The maximum collision speed at which there is no structural damage to the car body and the coupler.
  - (ii) The minimum collision speed at which the coupler energy absorption device fails.
  - (iii) The minimum speed at which actual structural damage commences.
  - (iv) The maximum speed at which the cab structural collapse features deform completely, without damage to the main car body structure.
- 4.8.7 The detailed proposal shall also specify the measures taken in the design to achieve the above

objectives and the proposed verification to satisfy the effectiveness of the design.

4.8.8 Deleted.

4.8.9 One train shall be fitted with strain-gauged and instrumented couplers so as to able to measure compressive and tensile loads being experienced by different couplers under different conditions of operation & testing(during commissioning) on main line.

Adequate provisions shall be made to monitor the data from these strain gauged couplers on TCMS. It shall be the responsibility of the Contractor to validate the instrumented couplers and to demonstrate that the loads being experienced by these couplers are within design limits, under different operating scenarios detailed by DMRC. Details shall be discussed during design stage.

#### 4.9 Under Floor Equipment Mounting

4.9.1 Equipment shall be mounted in accordance with IEC 1133: 1992 regarding weight distributions.

4.9.2 Routine maintenance and inspection will be carried out from the sides and underneath of the car. The Contractor may mount propulsion and auxiliary equipment using an optimum number of pre-wired, piped and tested modules, to ensure ease of access to equipment.

4.9.3 Equipment box covers shall be provided with simple secure locking devices, with easily visible markings to indicate locked position. The covers may be of stainless steel/Aluminum. The size and weight of the cover shall permit removal and manipulation by one person.

4.9.4 Covers shall be so designed that in the event of failure of a locking device in service, covers shall remain captured and shall not infringe the Kinematic Envelope. Otherwise, cover retention catches shall be provided to prevent covers from accidentally falling off. Covers shall open in a manner that will prevent injury by contact with sharp edges or live electrical contacts.

Pneumatic and brake equipment, isolating valves shall be easily accessible from the side.

4.9.5 The under-floor mounted equipment cases shall be constructed using materials (e.g. stainless steel/Aluminium) requiring no corrosion protection throughout the life of the car.

4.9.6 All under-floor-mounted rotating machinery shall be fitted with resilient mountings to eliminate transmission of mechanical vibrations to the car body. Rotating parts should also be adequately guarded and protected against ejection under failure conditions.

4.9.7 All equipment mountings must be designed such that in the event of mal-operation or failure, equipment will remain secure and within K.E.

4.9.8 Mounting arrangements shall ensure that under no circumstances the equipment would fall on line during operation. Contractor shall establish during design.

4.9.9 Design of carbody underframe and equipment layout shall consider quick re-railing of the car specifically in case of derailment at points and crossings. Re-railing points shall be located at suitable locations and detail re-railing procedure with normal Lucas tools shall advised and validated. It shall be possible to place the jack(s) beneath the coupler at agreed location for lifting and moving the car for re-railing purpose.

#### 4.10 Couplers and Draft-gear

4.10.1 General

The basic composition is six-car train. The cars shall be provided with automatic couplers and/or semi-permanent couplers as specified in Chapter 1.

4.10.2 Coupling Requirement

The automatic coupler shall, in conjunction with the draft-gear automatically effect mechanical and pneumatic coupling. It shall also permit operation (both couple/uncouple) manually from the track side or remotely from the driving console and saloon.

The coupler shall provide adequate support to the gangway with passengers. Alternative gangway support systems may be proposed. Full details shall be provided.

In order to meet emergency requirements of clearing a disabled train by a healthy train, the couplers in the proposed train shall be totally compatible for effecting safe mechanical and pneumatic coupling.



The coupler and draft-gear shall, in conjunction with the inter-car gangway, be capable of gathering, engaging and coupling units on all track conditions detailed in Chapter 3, Clause 3.14. Under these track conditions, coupling shall be achieved with the most adverse mismatch of car heights, caused by wheel wear, passenger loading, air spring deflection, and service tolerances.

The automatic coupler shall be equipped with a integral self-centring device to prevent the coupler from swinging transversely when uncoupled. However, the gathering range of the mechanical coupler shall be suitable for horizontal curves of 100m radius and vertical curves of 1500m radius.

Both coupling and uncoupling arrangements shall be fool proof and shall utilise both the hands with built in safety precautions against possible hazards.

The coupler shall not generally require any maintenance upto intermediate overhaul. Any greasing if required shall be in-situ only.

#### 4.10.3 Automatic Couplers: Protection

When uncoupled, auto-couplers shall be arranged so that pneumatic connections shall be automatically protected from the ingress of water and extraneous foreign matter.

Auto-couplers shall also incorporate provision for the selective isolation of air connections whilst remaining mechanically coupled.

The electromagnetic valves used for actuation of coupling / uncoupling action shall have IP protection of IP 65 and shall be proven in EMU metro operation for atleast 2 years.

#### 4.10.4 Semi-Permanent Couplers and Draft-gear

Semi- Permanent coupler should not sag in uncoupled condition and it should be possible to couple two halves of semi- permanent coupler without any external assistance. After coupling, such means shall not limit normal operating movement of the coupler. This arrangement shall accommodate the full range of height variation between adjacent vehicles when being coupled. The pneumatic connection between the cars of a unit shall be through the semi-permanent coupler.

Electrical end connections shall be semi-permanent. Uncoupling or re-coupling shall not damage these connections. It shall not be necessary to give preventative maintenance attention to these connections between vehicle overhauls.

#### 4.10.5 Draft-gear Design and Energy Absorption Requirements

The draft-gear shall meet the requirements specified in Clause 4.8.

#### 4.10.6 The coupler shall be maintained horizontal by means of easily adjustable supports, which shall take care of loss of coupler height within the car body.

#### 4.10.7 The weakest portion for parting shall be at the junction of the two coupler heads, interrupting pneumatic connections, and thus causing an instant emergency brake application.

#### 4.10.8 All the couplers (Auto, semi-permanent) shall have the shear-off functionality. Wearing parts/plates of the couplers shall give a service life of minimum fifteen years.

#### 4.11 Car Exterior

##### 4.11.1 The appearance of the car exterior must be of a modern and aesthetically pleasing profile and shall minimize the built up of dirt. Approval of the Engineer shall be obtained for car exterior. The car exterior finish with stainless steel body shall not require paint for protection.

##### 4.11.2 Proposals for measures that will maintain the original appearance of the car exterior from undue deterioration, staining or streaking, including appropriate chemical cleaners shall be submitted.

##### 4.11.3 The Project Owner's logo (to be advised after contract award) shall be applied on both sides of the car and also at the both ends. The car number shall be applied on both sides of each car at both ends, both externally and internally and also inside the driving console to be easily visible to the train operator and maintenance personnel.

##### 4.11.4 A longitudinal colour band and /or other branding image shall be provided along each side of each car. The colour scheme shall be agreed upon during the design review of the cars.

##### 4.11.5 Deleted.

##### 4.11.6 The cars shall be completely watertight, without using any sealing compound, and be able to withstand rain water protection test, as approved by the Engineer, simulating a train traveling at speed under severe climatic conditions of Mumbai as well as passage through automatic wash plants. If considered unavoidable, only weld-through sealants shall be provided. The external

sealants shall not be exposed to direct sunlight. The sealants life shall match with the life of the car body and detailed literature/catalogues shall be submitted to the Engineer and approval obtained prior to undertaking manufacture of car body.

4.11.7 The design of the car exterior shall generally be aesthetically pleasing, and shall minimize the build up of dirt.

#### 4.12 Driving car Front End Exterior

4.12.1 The driving car front end is required to house the following features and devices:

- (i) Windscreens (See 4.13.2) along with sun-blinds,
- (ii) Train Number Indicators (See Chapter 13)
- (iii) Destination Indicator (See Chapter 13).
- (iv) Head- and tail-lights (See Chapter 12).
- (v) Flasher Light (See Chapter 12).
- (vi) An electric horn, operable from the train operator's console (See Chapter 12).
- (vii) Windscreen and Detrainment Door wipers (See Chapter 12).
- (viii) Detrainment Door
- (ix) Front and Rear Cameras (See Chapter 13)

4.12.2 Suitable step arrangement at first door for entraining and detraining of train operators shall be provided and shall have anti slip surface. The material used should last at least for interval between Periodic overhauls of car body.

4.12.3 Deleted.

#### 4.13 Train Operator's Driving console

4.13.1 Driving console Layout

- (i) Driving console layout and facilities shall be designed to meet all possible modes of operation including UTO/non UTO, Manual Driving in line/depots/stabling yards etc.
- (ii) Suitable driving console shall be provided at each end of the train to manually operate the train. In addition, a suitable foldable seat for Train Operator shall also be provided under the driving console, which shall be used initially for running the train under GoA2 mode as well as in case the train operating under UTO is required to be driven by the TO under emergency conditions. A removable saloon to driving console partition shall be provided for each Driving Motor (DM) Car in all trains irrespective of mode of operation. The removable partition shall be of the full width of the car with a provision of access door between saloon side and driving console side with a suitable arrangement of locking mechanism (Refer ERTS 7.5).

It shall be possible to remove these partitions without disturbing the interior aesthetics. It shall also be possible to reinstall these partitions in the train, if required. The design shall be finalized by the Engineer during design stage.

- (iii) UTO shall be the predominant mode of train operation. In case the Employer does not engage UTO for any reason, the train operator will be onboard to drive the train under ATO or Manual Mode (under ATP). During such operations, the train operator shall be responsible for train safety and operation of the train as per the Employer's operating instructions and time tables.
- (iv) During UTO operation the driving console shall be concealed by an aesthetically matching cover (with car interiors). The cover shall have sufficient structural strength, vandalism proof, compatible with fire performance and suitably locked and secured. During the non UTO operation only authorised personnel can open the cover which shall be recorded and transmitted to the OCC.

Space for placing the covers shall be ensured when manual operation is required during UTO operation. Emergency detrainment door ramp (in folded condition) shall be suitably covered from inside of driving console and space for keeping this detrainment door cover shall be ensured.

- (v) In order to release maximum space when the saloon to driving console partition is removed during UTO and also to enhance the effectiveness of operation, the control equipment shall be installed at distributed locations without affecting the safety, maintainability and reliability of train operation. During the design and in the physical mock-up it shall be demonstrated that the removal of the



temporary partitions and other temporary fixtures shall be easily possible and space released for commuters giving good visibility of the driving console front.

#### 4.13.2 Windscreen

The Windscreen including glass of the detrainment door shall be constructed of toughened, laminated safety glass, and shall comply with the requirements of UIC 651, IS 2553 (Part-1 and 2), ECE Regulation-43, EN 15152, and UIC 566. The inner and outer surfaces of the windscreens shall be scratch resistant.

#### 4.13.3 Cab Front Cupboard

An emergency equipment cupboard shall be provided at suitable location and equipped with first Aid box, safety equipment including fire extinguishers (5 Kg capacity) etc.

#### 4.13.4 Destination and Train No. Indicators

The train destination and Train no. indicator shall be located at the top of and immediate behind windscreen at appropriate location (See Chapter 13).

#### 4.13.5 Driving Console Lighting

LED based lighting of the train operator's console shall meet the requirements of UIC 651 OR and EN 13272. The driving console area shall be provided with a ceiling lights harmonised with saloon lights and console lights (See Chapter 12).

#### 4.13.6 Train Operator's Seat (Removable)

The train operator's seat shall be cushioned, non slippery, ergonomically designed with back/lumber support using non-flammable materials and filling, and fully adjustable in the longitudinal and vertical directions. When operating in GoA3/4, this train operator seat shall be removed and suitable provision shall be made in the floor to ensure that no permanent marking remain on the floor. In addition, a suitable foldable seat for Train Operator shall also be provided under the driving console, which shall be used in case the train operating under UTO is required to be driven by the TO under emergency conditions.

#### 4.13.7 Not Used.

#### 4.13.8 Saloon-to-Driving console Door

There shall be a removable temporary door in the removable partition between the saloon and the driving console. (See Chapter 7).

#### 4.13.9 Not Used.

#### 4.13.10 Driving console Floor

The driving console floor shall be clear of all discontinuities, and shall not incorporate access panels to underfloor mounted equipment, junction boxes and cable ducts. It shall be possible to undertake water washing of the driving console floor without damage to the floor or equipment. The driving console floor material, the floor covering and general design shall be similar to the saloon interior floor (See clause 4.14).

#### 4.13.11 Not Used.

#### 4.13.12 Not Used.

4.13.13 Suitable 15A and 5A socket with suitable protection device shall be provided in the console and at both ends of the car for charging emergency light, use of cleaning machines etc.

4.13.14 Brush finished grab rails shall be provided at appropriate (more than one location) locations in the driving console.

4.13.15 An openable window on either side shall be provided in driving console area.

### 4.14 Saloon Interior

#### 4.14.1 General Considerations

- (i) The Contractor shall propose vehicle interior layouts, which incorporate a modern aesthetic approach with considerations to optimise passenger comfort, safety and security as well as to minimise noise in the saloon.
- (ii) It shall incorporate wide double leaf automatic doors along each side, longitudinal seating, enclosed

by stand-back areas and draught screens, grab-poles and rails, LED lighting, air conditioning outlet grilles, passenger information displays, public address loud speakers, and passenger alarm devices to permit passengers to make the train operator aware of problems.

- (iii) The body side and roof outer skin shall have a suitable thickness of approved acoustic and thermal insulating material bonded to their interior surfaces.
- (iv) The design of interior fittings shall be safe under all conditions of passenger impact, during emergency braking and buffing under fully loaded condition.
- (v) All non-metallic materials shall satisfy the fire property requirements of flammability, toxicity, smoke emission limitations etc. specified in EN45545 Part 1 to 7 latest editions or better equivalent international norms/standards applicable for similar metro operations.
- (vi) All interior surfaces must be finished with good blending and good slow ageing properties to provide a pleasant, high-quality interior and for ease of cleaning and maintenance. No material shall degrade or stain when exposed to food, drink, graffiti, or any cleaners used by the Maintenance Personnel. No material shall produce any odour that would be noticeable or irritating to passengers.
- (vii) All internal panel surfaces shall be smooth finished with modern low flammability, low smoke emission, anti-graffiti, and low toxicity materials. All internal panels shall be resistant to graffiti, scuffing, vandalism, and cleaning agents (properties of cleaning agent shall comply with the Anti-graffiti Protection Standard NFF 31-112). Rounded corners or covings shall be provided wherever mutually perpendicular flat plane surfaces abut. Metal sticking strips of 150mm depth with radiused coving are required on all exposed vertical surfaces above floor level.

All panels shall conform to ASTM D2563- level 1 and NFF 01-281 standards. The colour shall not fade or discolour with time, or change due to rubbing. Vacuum infusion process with in-mould heating, Non-Crimp Fabric with Phenolic or FR Grade Vinylester Resin (confirming to EN 45545-2), shall be used to get light weight panels having 60% or more fabric by volume.

Additives, fillers, monomers, catalysts, activators, pigments, fire retardants, and smoke inhibitors shall be added to the resin mixes to obtain finished products with the required strength requirements and the flammability requirements as mentioned in EN 45545 Part 2(Category 4-A, Hazard level HL3) latest editions. Antimony Trioxide shall not be used. Mineral filler shall not exceed 30 percent of the finished weight for any preformed matched die molding process.

To obtain desired colour with good surface finish, finished exposed gel-coated surfaces with a minimum gloss value of 85 when measured with a 60 degree gloss-meter as per EN ISO 2813, high scratch resistance and anti-graffiti properties, gel coat with layer of surface tissue be used in the moulds. The gel coat shall have a minimum thickness of 0.4 mm and a maximum thickness of 0.75 mm. Painting of panels shall not be permitted unless specifically approved by the Engineer. Hand laying process shall not be acceptable, unless specifically approved by the Engineer.

Alternatively, Contractor with the approval of Engineer may use Prepreg panels subjected to meeting the requirements of flammability, toxicity and smoke emission limitations etc. with suitable surface finish, scratch resistance and anti graffiti properties.

Also, Ceramic coated Aluminium panels preferably with Aluminium extrusion having suitable thickness, adequately stiffened may be considered. Ceramic coating shall be applied on both sides of Aluminium panels with thickness of 50 µm on front side and 20 µm on back side. The flatness of Aluminium side panels shall be controlled within 0.5 mm per 1m length. The panels shall have rubber packing on backside of the panel to prevent any bi-metallic corrosion.

Contractor shall submit details of processes and raw materials proposed to be used in manufacturing of different panels such as side panels, driver's desk, ceiling panels, End ceiling panels, inspection cover panels, door coving panels, ceiling coving panels etc. for approval of the Engineer during design stage.

Contractor must furnish details for different panels but not limited to properties such as Glass Content, Ultimate Tensile Strength, Tensile Modulus, Ultimate Flexural Strength, Flexural Modulus, Compression Strength, Compression Modulus and Impact Test complete with the test methods in compliance of relevant ISOs.

Contractor shall also submit 200 mm x 250 mm samples of each proposed material, indicating material finishes.



- (viii) As far as possible, fastening devices, hinges, fixings and securing screws shall not be visible from within the saloon.
- (ix) Gaps between all interior lining, panels kick strips, seat shell, etc. shall be kept to bare minimum. Suitable cushioning at panel joints shall be provided to suppress noise.
- (x) The area between top of body side windows and the ceiling shall be utilised for advertising displays. Ceiling shall be of honeycomb panel to minimise noise transmission inside the saloon.
- (xi) The Contractor shall propose arrangements for Line route maps, system route maps and advertisement holders in the saloon that are unobtrusive and easy to maintain. He may also propose alternative and additional display systems, which satisfy the above intentions.
- (xii) Equipment cupboards for housing equipment, for which access from the saloon is necessary, may be provided at the car body ends.
- (xiii) At least two fire extinguishers of the dry powder type of approximately 10 kg capacity shall be installed in each saloon, readily accessible and flush mounted on panel diagonally.
- (xiv) A dedicated space shall be provided in the Driving Motor car, near the first door of the car, to accommodate a wheelchair, complete with its occupant. Detailed proposals, including the need for a doorway flap or ramp shall be submitted and may be reflected in the appropriate mock-up.
- (xv) The Contractor shall provide all interior and exterior signages required by the Engineer for approval. All interior /exterior stickers/ signages strips / logo etc used in any location shall conform to international norms and must be in use in more than 5 different metros worldwide. The safety related signages shall be fluorescent. The signage used for marking wheel chair shall be placed on floor as per the standard signage. The Adhesion value of the signages after 24 hours of application shall be 1450-1500 gm/2.5cm. Contractor shall prepare detail plan for signages and stickers as followed in the metros worldwide for engineer's approval. The signages for emergencies shall be fluorescent types.
- (xvi) Each saloon shall have at least one 230V & 5A socket and two USB ports on both ends. Additionally, availability of two no. of USB ports at suitable location shall also be ensured at the unreserved seats which shall be finalized during design stage. These sockets and USB ports shall be used for mobile and laptop charging.
- (xvii) Space released due to GoA4, shall either be provided with seats or/and lumber support for standees.
- (xviii) Suitable fire and smoke detection system shall be provided inside the saloon as per ERTS clause 2.20.

#### 4.14.2 Windows

- (i) Saloon windows shall be provided and be flush mounted with the exterior of the car body.
- (ii) All windows, including those in Passenger Saloon Doors shall consist of the following as a minimum:
- Inner tempered glass ( minimum 5mm thick);
  - Air gap (6mm);
  - Double glazed laminated glass with PVB coating between them.
  - Minimum total thickness shall be 18 mm with noise attenuation shall be 33 dBA.
- (iii) All windows shall be designed to minimise solar gain and provide a level of thermal insulation consistent with the requirements of the HVAC system.
- (iv) Window units shall be modular units, and shall be replaceable with minimum disturbance to the rest of the vehicle.
- (v) Large window openings are preferred to permit standing passengers a wider view. The size of the windows shall be subject to review by the Engineer
- (vi) Each window, including glazing shall have sufficient strength to resist penetration of solid steel ball when tested as per annexure 'A' of IS: 2553 Part-II.
- (vii) All side windows shall transmit less than 5% of the incident ultra violet radiation. All windows shall transmit between 50% and 55% of incident visible light.

- (viii) Deleted.
- (ix) Window seals shall be designed to prevent ingress of water to the inside of walls. Use of rubber extrusions is preferred to make the mounting watertight. The sealing material shall be so selected that it lasts at least for the interval between major overhauls of car body.
- 4.14.3 Passenger Saloon Doors
- Each car shall have eight pairs of electrically operated, externally hung, sliding bi-parting doors, four per side (See Chapter 7).
- 4.14.4 Seats
- (i) For all cars including 'First Class' Car, the seating arrangement shall be discussed during design and shall be maximised by avoiding cubicles in the saloon space. The seats shall be designed to ensure they are:
- Comfortable with lumbar support & aesthetically pleasing.
  - Easily cleanable, repairable and changeable and will not be adversely affected by normal cleaning agents.
  - For all cars except 'First Class' Car, Durable, stainless steel/ SMC (Sheet Moulding Compound) with PiMC (Powder in-Mould Coating) FRP, light weight, fire resistant, anti graffiti, scratch and vandalism proof seats shall be used. In case of FRP seats, high level of anti-scratch resistance as per NF T51-113 & EN438-2 should be followed and according to EN438-2, minimum rating of 3 for scratch resistance and above shall be preferred. Graffiti shall be easily cleaned off from the seats by using approved cleaning agents. Details of such agents shall be furnished and validated. Additional mineral fillers may be added to enhance fire retardant property, flex modulus and surface finish.  
In case of FRP seats, the colour shall be uniform throughout its thickness and shall have same top surface colour so that the scratches are generally not visible. Additional anti-scratch protection may be provided. Contractor shall get specific approval of fiber reinforcement and polymer matrix materials from the Engineer.
  - Mountings shall be capable of withstanding the loads arising in service conditions.
  - Sitting surface may be metal/non-metal. In case of metal surface, seat shall be made of anti-slip bucket type stainless steel.
  - Provide some resistance to passenger movement longitudinally along the vehicle during acceleration and braking.
  - The proposed seats should have been in use in similar metros worldwide.
- (ii) The colour scheme and design shall be selected by the engineer during design.
- (iii) Behaviour of seats at static, fatigue, vibrations, impact stress shall be tested as per NFF 31-119 and indentation test shall be tested as per ISO 2439. The indentation hardness shall be similar to industry standards. The indentation hardness and depth shall be measured first be tested initially and then at 80,000 cycle intervals.  
The natural frequency of the seat system (including seated passengers, each weighing 65 kg) shall be greater than 1.4 times the natural frequency of the carbody natural bending frequency.
- (iv) Unpainted seats shall be used. A very high order gloss level shall be achieved and permitted gloss level shall not be less than 80 measured as per the relevant standard. The seats shall be subjected to endurance tests up to 300,000 cycles. In order to release space in the driving console area, auxiliary equipment /panels etc. may have to be placed under the seat. The equipment heat shall not affect the seat and suitable arrangement shall be made for its dissipation. The seat/its base shall be provided with arrangement with 'Sealed for life' hydraulic jack to easily lift by one person it for maintenance purpose. Seating passengers can block the air flow into these equipment/panels. Care shall be taken in design of ventilation/cooling arrangement of these equipment.
- (v) Seat modules in similar situations in a vehicle shall be interchangeable. It is preferable that only one style of module be used throughout the train.
- (vi) Seats in 'First Class' DM car shall have improved passenger comfort, including in the areas of seat bottom and back angles, seat width, lumbar support, entry/egress from the seat. The foam selected for the seat back and bottom cushions shall be of fire retardant-treated type. The Contractor shall submit details of seating which will be finalized by the Engineer during design stage.
- (vii) Equipment requiring periodic maintenance shall not be installed underneath seats.
- (viii) **Submittals**



- All drawings and calculations necessary to evaluate and manufacture all the types of complete seat assemblies used in the car shall be provided.
- One sample of each type of seat shall be provided.
- Seat layout drawings showing the location of all seats in the car for each car type.
- Inspection procedure for the inspection of seat assemblies and components to ensure compliance with the Specification and the requirements outlined in the part and assembly drawings of all seating components.
- A2 Size (420 mm x 594 mm), color, three-dimensional photo-realistic renderings of each type of seating assembly shall be provided before any engineering drawings are provided. The renderings shall be updated and resubmitted after the seat outline drawings are approved by the Engineer.

#### 4.14.5 Draught Screens

- (i) Beside all passenger access body-side doorways, shall be provided a longitudinal space, providing a "stand-back" position for passengers to manoeuvre themselves into position when nearing their station.
- (ii) Beyond the stand back area and at the end of the adjacent longitudinal seat a draught screen shall be installed.
- (iii) The draught screens shall be formed from tubular metal grab poles, fitted with clear safety toughened glass, in such a way as to provide uninhibited hand holds to passengers within reach of the tubular metal sections. Bump support/Lumber support arrangement shall be at suitable location as decided by the Engineer.

Draught Screen shall be adequately supported and the packing material used should not come out during the service life.

- (iv) The strength of the draught screens shall be such that passenger loadings shall not produce any permanent deformation, damage or displacement.
- (v) Deleted.

#### 4.14.6 Grab Poles and Rails

- (i) Stainless steel grab poles and rails shall be provided in the standing areas of the saloon for the comfort and safety of standing passengers.
- (ii) Grab poles shall have not less than three vertical arms for increased accessibility. However, space between the vertical arms shall be limited to ensure that no entrapment of any part of the body is possible.
- (iii) Sufficient margin shall be available in the top guide so as to ensure that under extreme loading conditions, the grab poles shall not become free.
- (iv) The grab poles and rails shall suffer no permanent deformation when subject to loading conditions arising in service, in accordance with UIC 566/EN 12663. The mounting of grab poles considers the movement of floating floor for passenger load of 10 passenger/m<sup>2</sup> and shall ensure free movement in the worst possible scenario.
- (v) Grab poles and rails in the DM and T/M car shall be provided to cover maximum number standing passengers. As a minimum 3 rows of longitudinal bars shall be provided throughout the saloon. The bars shall be suitably contoured in the door area to facilitate easy flow of passengers. The layouts shall be proposed by contractor during design and shall be decided during mock up. The decision of engineer shall be final. Stainless steel grab handles (sample shall be got approved from Engineer during Mock up review), widely used in at least five metros worldwide, shall be used.

Stainless steel grab handles with minimum five handles per meter of grab rail shall be provided. Additional Stainless steel grab rails shall also be provided at the entrance (both sides) of each door and also near gangway as decided by the engineer during Mock up review.

- (vi) Grab rails and stanchions in saloon area shall be brush finished.
- (vii) The Contractor shall incorporate his proposals into the mock up, for consideration. Detailed arrangements shall be finalized and got approved from the Engineer during the mockup finalization



stage. The decision of the Engineer shall be final and binding.

- (viii) The completely assembled grab handles shall be subjected to "pull off test" to measure the maximum load they can withstand. A minimum load of 2500N shall be achieved. The fully assembled grab handle shall be subjected to an endurance test with the following basic conditions:
- a) Load: 35kg vertical
  - b) Cycles: 300,000 cycles minimum
  - c) Bending Angle:  $\pm 45$  degrees
  - d) Frequency: Each cycle to consist of movement of the handle from one extreme to another extreme and back within one second.

Any other test considered essential for the grab handle test to be included in the test plan.

- (ix) Grab rails shall be so designed that they do not hinder passengers view of door/PEA(Passenger Emergency Alarm) device in CCTV.

#### 4.14.7 Interior Lighting

See Chapter 12 for details.

#### 4.14.8 Floor

- (i) The non-skid floor structure shall be of floating floor type. Aluminium honeycomb sandwiched type floating floor with suitable noise, vibration and heat insulation, duly supported on rubber cones will be preferred. Alternatively, the floor may comprise of ply board with cork inlay/Plymetal, rubber cushion, glass wool insulation and floor covering subject to its conformance with EN45545 part 1 to 7 Latest editions to achieve low noise level inside the cars and less weight. The floor shall be designed to minimise the life cycle cost of the floor over 35 years. Subject to submission of complete details and approval by the Engineer & for better noise attenuation level of the floor and conformance to EN45545 part 1 to 7 Latest editions or better equivalent international standard as specified in ERTS 2.5.8, any suitable alternate design of floating floor can also be considered.
- (ii) The floor, and its mounting structure, shall be designed to withstand specified loads that may be applied over 35 years in normal operation of the consist. The minimum thickness of the floor structure shall be 80 mm. There shall be no hatches in the floor or passenger areas. Floor hatches in driving console shall be avoided.
- (iii) The floor structure shall provide a high resistance barrier to fire and to noise generated beneath the vehicle. Test reports shall be submitted. At all door openings, the floor shall make a water-tight connection. No opening in the sub-floor is permitted.
- (iv) The floor covering shall be anti-slip, waterproofed and sealed, non-skid, resistant to wear and staining shall not trap dust, and shall be easily cleaned using conventional floor cleaning machines/methods and media. The floor covering shall meet the requirements of EN45545 part 1 to 7 Latest editions in respect of fire, smoke and toxicity. The Contractor shall ensure even, uniform and gapless joints. The width of the roll shall be selected to ensure the joint, if any, is only to the farthest from centre of the car. Due to heavy dusty environmental conditions, lot of abrasive dust gets accumulated on the floor within short time and gets stick to it making it difficult to clean by normal means. Contractor shall propose suitable cleaning machines and liquid (with suitable local equivalent) and demonstrate the cleaning procedure to the satisfaction of engineer and without any damage to flooring on long term basis. At least three sets of Machines and shall be supplied by the contractor without any extra cost for each depot. The flooring shall have high abrasion resistance as per ISO-4649 and shall be compliant with relevant EN/ISO standards. It shall also have provision for inlaid logos for handicapped persons etc.
- (v) The floor design shall allow the floor covering to be removed without damage to the floor sub-structure.
- (vi) The total floor structure shall provide an effective fire barrier for a minimum of 30 minutes to be validated as per EN45545 part 1 to 7 Latest editions or better equivalent standards applicable for similar metro operations.
- (vii) The sub-floor should be insulated for anti-drumming and noise suppression.
- (viii) Floor covering shall have a design life of not less than 20 years.



#### 4.15 Inter-Car Gangways

Single piece/Double piece, single skin/double skin with interior panel gangway suitably protected from heat and dust (subject to Engineer's approval) with suitable clamping and jointing arrangement on both ends with saloon end walls shall be provided within the unit. The attenuation of outside noise through the gangway shall not be less than 33 dB. In case of separation of cars the gangways shall have securing arrangement and shall not get damaged or de-shaped. Suitable form of guiding pin/plate etc. shall be provided so that the coupling /uncoupling of gangways can be carried out by one person.

##### 4.15.1 Exterior

- (i) The gangways, when coupled shall be completely weatherproof and draught proof.
- (ii) The gap between the station platform edge and the exterior of the inter-car gangway shall be minimised.
- (iii) The gangway structure shall lock securely at top and bottom. Locking and unlocking shall be by manual means with single operation levers one each for gathering and latching functionalities. The levers shall not be easily accessible to commuters.
- (iv) The means of uncoupling a semi-permanently coupled pair of cars, in workshop conditions shall be described by the Contractor.
- (v) All inter-car gangway structures shall be totally interchangeable with one another.
- (vi) To protect the interior of the vehicles when stabled as units, (i.e. not as a 6-car rake), from inclement weather, temporary gangway end covers shall be provided. The covers shall be sufficiently robust to provide good protection, but sufficiently light weight to permit fitting and removal by one person.
- (vii) The covers shall be lockable in position to withstand high wind conditions. The Tenderer shall include in his price for twelve such covers.
- (viii) The location of drain holes in the frame shall be such that water does not fall and corrode the junction box or coupler beneath.

##### 4.15.2 Interior

- (i) The inter-car gangways shall be arranged so that litter left in the gangway cannot accumulate, and is readily removable, without having to disconnect gangways or remove access covers.
- (ii) The headroom in the inter-car gangway area shall be at least 1900mm, and the clear width through at least 1400mm.
- (iii) The interior design shall be fitted with smooth and aesthetically pleasing finish and shall ensure that no potential finger or dirt traps exist.
- (iv) It shall not be possible for a person to move apart parts of the gangway interior cladding in such a way as to gain access to the exterior of the vehicle between components of the gangway, under any circumstances.
- (v) The locking arrangement shall not be accessible to the commuters.

##### 4.15.3 Gangway Floor

- (i) The floor through the inter-car gangway shall be maintained as nearly as possible at the same height as the rest of the car floor. The height difference shall be kept to a minimum, and at no point shall it exceed 20mm difference from the remainder of the floor. Height changes shall be ramped so as not to cause inconvenience to passengers.
- (ii) Vertical gaps between the hinged moving tread-plates of the inter-car gangway and the general floor level of the car shall not exceed 5mm. The means shall be provided to minimise wear of the floor by the sliding action of each moving tread plate.
- (iii) The design of the floor shall be such that the relative movement between adjacent vehicle ends does not cause sliding floor plates to lift in such a way as could cause injury, in particular to sandal-clad or bare feet.
- (iv) Heat and sound insulation measures sufficient to meet internal noise levels and HVAC requirements of the car body shall be provided.
- (v) Sealing of the gangway shall eliminate leakage of any water into the saloon area. Also, the water from saloon shall not go and collect below the gangway floor.

- (vi) The rubber/elastomer elements of the gangway shall give a service life of minimum eight years. However, bellows shall give the service life of minimum fifteen years.

#### 4.15.4 Gangway Strength

- (i) The gangway floor shall be designed to meet the same strength requirements as the rest of the car floor.
- (ii) The gangway shall withstand without permanent deformation the following loads:
- A differential pressure between inside and outside of the gangway of  $\pm 2.5\text{kN/m}^2$ .
  - A concentrated perpendicular load, acting from within the gangway, of 1000N applied over an area of  $0.1\text{m}^2$  anywhere on the surface of the side walls.

#### 4.15.5 Deleted.

### 4.16 Car Roof and Roof Mounted Equipment

#### 4.16.1 Roof Structure

- (i) Carbody roof shall be curved to suit aesthetics and shall be got approved from engineer. Roof shall be constructed of stainless steel sheets of minimum 1 mm thickness. The roof shall be 'passivated' involving chemical treatment with dilute acid solution for the purpose of removal of free iron or other foreign matter, before introduction of cars in revenue service
- (ii) In Mumbai area, incidences of stray wire being dropped by birds etc are quite frequent. In many cases this has fallen on OCS and roof equipment mounted on the body. These resulted not only in interrupting train running and power supply system but also withdrawal of rakes from revenue service and also puncturing of roof sheets. To obviate these problems, suitable design arrangements for provision of suitable insulation (for 25 kV single phase) of all live parts on the roof (excepting pantograph pan) shall be provided and methodology shall be finalized during Pre-Final Design Stage with the approval of Engineer.
- (iii) Sometimes these wires are long enough to bridge OCS and body of cars. Design shall ensure that puncturing of the roof is avoided to the maximum extent possible. In such cases, non metallic cab mask is found to experience severe damage. Suitable design provisions shall be made to minimise such instances.
- (iv) Roof design shall be such that there shall be no possibility of water stagnation at any part of the roof.
- (v) All sub components of the roof or roof & equipment bases, shall be continuously welded/brazed to ensure that there is no ingress of rain water between any joints on the roof. Use of water sealant putty alone for water sealant is not acceptable. However, such putty of proven make can be used along with the continuously brazed/welded joints, if required.
- (vi) The Contractor shall submit proposals for review and approval by the Engineer.

#### 4.16.2 HVAC Equipment and Duct

Packageunits shall be mounted at each end of the car roof, housed in suitable watertight wells in the car roof structure. The wells shall be provided with adequate, double sealed connections to the main conditioned air ducting, electrical supply and condensate drains. Conditioned air shall be fed into thermally insulated ducting. The duct shall be split diagonally from end to end to distribute air evenly throughout the length of the car. In the event of the failure of one HVAC unit conditioned air shall be made available throughout the length of car including driving console in DM car. The design of the duct shall comply with the requirements laid down in ERTS Chapter 11.

Suitable arrangement shall be provided for providing sufficient quantity of conditioned air in the driving console area as well as in the front console and cubicles. The temperature in the driving console area shall be same as achieved in the saloon.

Suitable arrangement shall be provided to drainout the condensate water from the lowest point of the HVAC unit. Service life of the drain holes shall be minimum 35 years. The drain arrangement shall be robust and of adequate size, shall be designed to prevent choking and shall be easy to clean and design shall be finalised during Pre-Final Design Stage. Under no circumstances, the condensed water shall spill inside the saloon or on the platform.

HVAC covers in the roof except for grill of condenser fan shall be of sufficient strength and no restriction shall be placed for movement of maintenance personnel on the HVAC roof.



Deposition of dust in the duct shall be avoided to the maximum extent. It shall be possible to easily clean the duct. Cleaning of the duct shall be simple and Contractor shall suggest necessary equipment required for dust removal and sanitization against fungal growth etc. Contractor shall provide minimum two sets of duct cleaning equipment in each Depot. Thermal insulation and sealing of duct shall have zero calorific value. Tapes and other adhesive materials used in ducts shall have minimal calorific value and shall be fire retardant.

#### 4.16.3 Roof Drainage

The Contractor shall ensure adequate water drainage from the both ends of the roof, such that no water shall be discharged into the vicinity of the passenger doorways. The water shall not accumulate in the rain gutters and shall be easily discharged through adequate sized pipes at levels below the floor level and sufficiently away from the track. Hose/Rubber fittings are not preferred in the discharge pipe and steel pipe fittings shall be preferred. In case, rubber pipe connections are unavoidable due to tolerance clearance issues, they can be used only at one location provided the life of rubber used shall be more than 15 years and suitable window arrangement on the carbody for its replacement shall be available.

The rain gutter shall be so mounted on the car body such that there is no possibility of water seepage from gutter on the body.

The rain gutter stainless steel sheet shall be of same finish as side wall. The joints shall be designed such that no water seepage shall be possible at joints. The surface finish criteria for rain gutter shall be same as applicable for the side wall.

The drainage shall be so designed to eliminate the requirement for unblocking of leaves and other debris. The drainage arrangement shall be suitable for use with, and not cause damage to the brushes of automatic train wash plants.

#### 4.17 Design of Exhaust Air Path

Exhaust air exit path shall be provided through openings below the seats, allowing the interior air to pass through the gap between the inner and outer layers of side walls and discharging to atmosphere from outlets provided on the roof at centre and as well as at the ends. Exhaust airpaths/ducts should be metallic, constructed of stainless steel or Aluminium, and having anti-corrosion coatings. They should be sloped to drain any condensate water to the outside of the car. Gravity dampers and water eliminators should be provided at exhaust air outlets to prevent air back flow and water ingestion from rain or car washer. Exhaust grills should be located on the car body areas where the outside static pressure disturbances are minimum, so as to prevent large fluctuations of the car interior static pressure on train runs. The design of exhaust chimney shall be suitably designed to prevent water ingress inside saloon area and between the inner and outer layers of side walls.

#### 4.18 Obstruction Deflection & Derailment Detection Device (ODD)

4.18.1 At the front of the DM car, an obstruction deflection & derailment detection device shall be installed to push away objects on track to avoid derailment along with derailment detection functionality. The actuation of the obstruction deflection & derailment detection device due to impact of the object, shall initiate the emergency brake and shall be recorded by the TCMS. The design of obstruction deflection & derailment detection device and its mounting arrangement shall be proven and should be in use in similar metro applications.

4.18.2 The Contractor shall submit the detailed calculation of design proof load, installation arrangement, safety against derailment, energy absorbing capabilities etc. during detailed design.

4.18.3 Obstruction deflection & derailment detection device mounted on the leading bogie shall be preferred. Detailed arrangement shall however, be discussed during the detailed design and approval of the Engineer shall be obtained. Engineer decision shall be final and binding.

**4.19 Deliverables**

4.19.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	4.14.8 (iv)	Conventional floor cleaning machines.	At least three sets of Machines for each depot.
2.	4.16.2 & 11.2.8	Duct cleaning equipment.	Minimum two sets of duct cleaning equipment in each Depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



## 5. BOGIES

### 5.1 General Requirements and Features

5.1.1 The bogies proposed to be supplied against the tender shall be of proven design principles. Similar bogies as proposed for this tender, shall have been in use and have established their satisfactory performance and reliability on at least three mass rapid transit systems in revenue service over a period of three years or more (in each MRTS) either outside the country of origin or in Indian Metros. The Tenderer should submit performance certificate on the letterhead of metro operator, confirming that the supplied bogies have completed satisfactory performance for more than five years. Tenderers must submit following information with their offer

- (i) Statement indicating commissioning dates of bogies and numbers, duly certified by the metro operators.
  - (ii) Details of the designer and manufacturer (complete address) of the supplied bogies.
  - (iii) Following details of the metro systems where the bogies are in operation:
    - No. of stations with details of inter-station distances
    - Average annual kilometers earned (duly certified by the metro operators)
    - Details of sharp curves (minimum radii)
    - The Tenderers shall submit the details in the proforma specified in 'Annexure TBS-3' of 'Technical Bid Submission Sheet'.
    - In case, the Tenderer is not the manufacturer of bogies and intends to procure the bogies proposed to be supplied against the tender from a sub-contractor, the proposed sub-contractor for the bogie shall meet the eligibility requirements stated above. Further, during contract execution, the manufacture of the bogies by the sub-contractor shall be required to be inspected and certified by a reputed Third Party Inspecting Agency engaged by the Contractor having sufficient previous experience of similar nature. The contractor's proposal for engaging Third Party Inspecting Agency with detailed terms of reference (TOR) indicating detailed scope of work shall be submitted to Engineer for the approval not later than six (06) months from the commencement date. However, maintaining the quality standards, ensuring performance requirement and timely delivery shall be the sole responsibility of the contractor.
- 5.1.2 It shall be manufactured to continue in service, under all operating conditions for at least 35 years, assuming normal wear and tear, and maintenance. During that period, there shall be no major rebuild, repair or strengthening of any bogie structural members.
- 5.1.3 The bogies shall be of the two axle bolster less type incorporating a primary suspension system of proven helical coil steel-springs. Vertical damper shall be provided with primary suspension. Calculation supporting the selection of axles and bearings shall be submitted for review and approval by the Engineer. Bogie body connection shall preferably be through resilient transmission bar arrangement.
- 5.1.4 The bogies for all trains under this contract shall be identical to the maximum extent possible. DM, T and M car bogies shall have interchangeable components to the maximum extent possible. The bogie components and suspension components shall be common for all bogies.
- 5.1.5 Car body and bogie construction tolerances and distortions shall be controlled within the specified limited tolerances. If necessary suitable shims to be provided to maintain the tolerances. If shims are required for permanent use, the same shall become a permanent fixture on the bogie and or carbody.
- 5.1.6 The design shall provide means for easy compensation for wheel wear and loss of height in the bogie resulting from other causes.
- 5.1.7 The bogie and bogie mounted equipment shall be designed to minimize un sprung mass.
- 5.1.8 The bogies offered shall permit the cars to negotiate curves on plain track and through turnouts as per parameters given in chapter 3.
- 5.1.9 The bogies shall be provided with optimised suspension. Suspension would not be acceptable if bogie shows tendency to hunt up to the maximum test speed.
- 5.1.10 All Rubber/ rubber-metal-moulded items used in suspension shall be type tested for specified temperature and humidity conditions.

5.1.11 The bogie shall be capable of negotiating Depot curves of 100 m radius and main line curves of 110 m radius, turnout up to 1 in 7 & 190m radius. The axle yaw stiffness and the rotational resistance of the complete bogie shall be such that lateral flange forces generated when negotiating the track alignments for the route specified do not lead to excessive rail wear, wheel flange wear and noise, but shall be sufficient to obviate bogie or wheel set hunting.

5.1.12 The design life of the car and the bogie shall not need any rebuilding, repair or strengthening of structural members.

The service life of rubber bonded metal components shall not be less than 8 years and shall be warranted for the same.

## 5.2 Dynamic Requirements

5.2.1 Suspension characteristics shall be selected so as to avoid resonance between the various elements of the vehicle system including the car body. Bogie and body frequencies shall be suitably separated.

5.2.2 All vehicles shall be so designed that no part of the car shall infringe the Kinematic Envelope at any speed up to 90 kmph.

5.2.3 The bogie suspension, in conjunction with the car body, shall be designed to enable cars to operate satisfactorily on track with the maximum specified track twist. The maximum offloading of wheels ' $\Delta Q/Q$ ' shall not exceed 60% of nominal wheel load for bogie twist and vehicle body twist as per EN 14363 in both inflated and deflated conditions.

5.2.4 The axle yaw stiffness, and the rotational resistance of the complete bogie shall be such that lateral flange forces generated when negotiating the track alignments for the route specified are not so high as to lead to excessive rail wear and wheel flange wear, but shall be sufficient to obviate bogie or wheel set hunting.

5.2.5 The Contractor shall submit calculations to confirm that the derailment quotient  $Y/Q$  shall not exceed 1.0 at rail-wheel level under the most adverse conditions, where  $Y$  &  $Q$  are the instantaneous lateral force on the wheel flange and the instantaneous vertical load on that wheel tread respectively.

5.2.6 The bogie rotational resistance (X factor) test under inflated and deflated air spring conditions would be carried out at the manufacturer's works under AW0 and AW3 conditions, the value of which should not exceed 0.1 at rotational speed of 1 degrees/second.

5.2.7 Vehicle Dynamic Analysis of Bogie:

A Dynamic Analysis, to evaluate the running behavior of the vehicle with the proposed bogie design, shall be carried out by means of theoretical calculations applying multi-body simulation techniques. Proven validated software shall be used. The following parameters, at the minimum, shall be evaluated / analyzed.

- (i) Natural frequencies of the suspension.
- (ii) Stability of the vehicle.
- (iii)  $\Delta Q/Q$  for the track twist.
- (iv) Bogie rotational resistance.
- (v) Wheel wear index at the tread and flange.
- (vi) Derailment quotient  $Y/Q$ .
- (vii) Carbody accelerations.
- (viii) Curving capability and any tendency to hunt.

The Contractor shall submit a proposal covering the scope of the analysis and the model for review by the Engineer.

5.2.8 During design stage the Employer may engage an experienced International Consultant who shall also carry out validation of the design of the proposed bogie. The consultant's report shall be discussed with the contractor's design engineer and changes/improvements if required to be implemented shall be considered by the Contractor.

## 5.3 Bogie Construction: Bogie Frame

5.3.1 The bogie frames shall be of fabricated, robust construction, using high tensile carbon steel to EN10025/ JIS G3114 or an approved international standard, capable of withstanding heavy duty,



the design incorporating adequate safety margins. The bogie frame construction shall be consistent with good mechanical design, be as light as possible. Use of cast steel inserts of acceptable grade in fabrication with specific prior approval of the Engineer in the bogie may be permitted.

- 5.3.2 The Contractor shall submit for review detailed calculations, including a finite element analysis under different boundary conditions, to demonstrate that the strength of the bogie frame is adequate for the specified loading.
- 5.3.3 The bogie frames for all the cars shall be identical unless justified otherwise.
- 5.3.4 The Contractor shall undertake full static load test, fatigue load test and suitable non-destructive tests on a pre-production bogie frame and submit the report. The strain gauge fixing locations and the application of forces for these tests shall be approved by the Engineer before starting the testing. These tests have to be done as per UIC 615 and UIC 515 or EN 13749.
- 5.3.5 All fasteners for bogie mounted equipment or components shall be positively locked. Use of self locking Nuts alone shall not be acceptable. However, self locking nuts with lock washers would be acceptable.
- 5.3.6 Adequate corrosion protection shall be provided. A corrosion protection control programme for the bogie shall be submitted. This shall comprise of paint protection system of external surfaces. The internal areas of the frame shall be completely sealed to avoid moisture ingress after the internal surfaces are protected from corrosion by suitable corrosion resistance substance or any other alternative measure. The corrosion protection plan shall be submitted and got approved during detail design.

#### 5.4 Bogie Construction: Primary and Secondary Suspension

- 5.4.1 The Contractor shall submit a proposal for the primary suspension system of proven helical coil steel springs. Vertical damper shall be provided with primary suspension and secondary pneumatic suspension system, and contractor shall declare the estimated mean service life for operation in the Mumbai environment. Quality of dampers used shall be very high and guaranteed against any oil leakage/oozing.

Use of Chrome vanadium grade Steel as per EN10089 for helical coil primary suspension system design shall be ensured.

- 5.4.2 Secondary air suspension shall be installed to provide automatic vehicle body to bogie height adjustment, functional for all vehicle-loading conditions. The Contractor shall submit complete details and calculations of the proposed suspension (asymmetrical/symmetrical) during Pre-Final Design Stage for review and approval of the Engineer.
- 5.4.3 Vehicle height variation due to wheel wear and re-profiling shall be adjusted by packing. Preferably, this shall be made possible without disconnection or removal of the car body from the bogie. Leveling of the car once adjusted, shall not get disturbed during operation or otherwise and shall not require any adjustment except for usual adjustments due to wheel wear and placement of shims. The maximum floor height reduction on this account shall be for review by the Engineer. The load sensors shall be placed at the farthest end towards the side wall.

The minimum clearance of bogie-mounted equipment from rail level for a fully loaded car under worst conditions\*(\*worst condition means wheels with maximum tread wear and primary springs with maximum deflection) shall not be less than 65 mm in static condition and 50 mm in dynamic condition.

The minimum clearance of car body-mounted equipment from rail level for a fully loaded car under worst conditions\*(\*worst condition means wheels with maximum tread wear and primary springs with maximum deflection) shall not be less than 102 mm in static condition.

- 5.4.4 Secondary suspension emergency springs, which shall become operative in the event of full deflation of air springs, shall be fitted. The car shall remain dynamically stable throughout the full speed range (0 to 90 kmph) of the train under all conditions when secondary air springs are functional. In the event of one air spring becoming wholly or partially deflated on any bogie, the complete air spring system of that bogie shall be correspondingly exhausted to ensure that the car body remains level laterally, and can continue to operate safely. The safe speed at which the train can operate will be determined through oscillation trials to the same safety and statutory limits as per clause 15.5, with either complete (full coach) or partial deflation (one bogie) of the secondary springs.
- 5.4.5 Hydraulic dampers of suitable capacity shall be provided symmetrically to control and limit the vertical and lateral oscillation of the car body. The damping factors are to satisfy the provisions given in table 15.1B. The damping factor in vertical mode, by wedge test, when tested using a

wedge of 18mm thickness should be between 0.20 and 0.25. The damping factor in lateral mode when measured by "quick release side pull test" should be between 0.30 and 0.40. Suspension will not be considered acceptable if maximum acceleration and spring displacements do not decay within 2-3 cycles.

No leakages of any kind shall be permitted. The life of the dampers shall be minimum 10 years.

- 5.4.6 The air spring pressure shall also be used to provide an average signal input to the load weighing equipment for load compensation of the propulsion, brakes and air-conditioning systems. If the load signal fails, the system shall default to the maximum laden condition. Air pressures of all the four air springs (per car) shall be taken accurately to determine the actual average load.
- 5.4.7 The lateral stop shall be cushioned using a properly designed stiffness value. The lateral stops shall be sourced from Vendors having proven experience. Specific approval shall be obtained from the engineer.
- 5.4.8 The air springs shall have over inflation protection. The maximum permissible increase in height will be decided during detailed design stage.
- 5.4.9 Deleted.
- 5.4.10 The design life of secondary suspension air bags (all inclusive) shall not be less than 12 years. The air bags and its components shall not crack/shear/balloon/ burst or deteriorate in its performance during its design life.

## 5.5 Bogie to Body Connection

- 5.5.1 The car body bogie connection shall be capable of permitting the full range of bogie movements without excessive restraint.
- 5.5.2 The bogie shall be attached to the car body in such a way as to permit lifting of car body and bogies as a complete unit. The Contractor shall indicate the minimum safety factor used, taking account of the yield stress for all support members.
- 5.5.3 Traction linkage(s) shall be provided, and located such that the ride characteristic of the vehicle is devoid of any pronounced fore- and-aft and pitching motion. Single traction link (Mono-link) is preferable.
- 5.5.4 The car body to bogie connection shall withstand the following loads without permanent deformation:
- (i) A vertical load of 0.75 times the fully loaded weight of the carbody (excluding bogies)
  - (ii) A lateral load of half fully loaded body weight subjected to an acceleration of  $\pm 1.1g$ .
  - (iii) A longitudinal load equivalent to the bogie mass subjected to an acceleration of  $\pm 3.0g$ .
- 5.5.5 Bogie and car body connection shall be designed to avoid the transmission of noise and vibration.

## 5.6 Bogie Strength

- 5.6.1 The mechanical strength of the bogie frame shall comply with the requirements of UIC 615-4, UIC 515-4 and EN 13749 for static test under exceptional loads and fatigue tests. The maximum stress developed under static load shall not exceed 85% of the yield strength of the material. The dynamic effects due to the inertia of the motors and transmission shall also be simulated along with traction and braking forces.
- 5.6.2 The bogie frames shall be able to withstand a longitudinal shock load of 5g without failure. This shall be taken as occurring simultaneously with the fully laden vertical load.
- 5.6.3 The axle shall be designed in accordance with UIC 515-3/EN 13103/EN 13104.
- 5.6.4 The number of seated passengers shall be taken as one per seat, and standing passengers as 10/m<sup>2</sup> for all the above-mentioned strength analyses except for fatigue test. The fatigue load shall be decided based on actual loading which shall correspond to AW2 loading conditions. The loading cycles shall be as specified in respective UIC. There shall not be any crack at the end of any stage of loading cycles. The passenger weight for this calculation shall be taken as 65kg/person.

## 5.7 Bogie Mounted Equipment

- 5.7.1 The train equipment shall conform to IEC 61371/IEC61373 in respect of shocks and vibrations including the endurance limits. These shall be incorporated in the type test of the equipment.

## 5.8 Finite Element Analysis



5.8.1 Finite element analysis shall be demonstrated using validated software, and detailed calculations submitted for the above-mentioned strengths (including static and fatigue loads).

#### 5.9 Motor Suspension

5.9.1 The traction motor shall be bogie frame mounted, complete with suitable drive and suspension. Mounting arrangement shall ensure that under no circumstances traction motor would fall on line during operation. Contractor shall establish during design.

5.9.2 Traction motors and drives shall be easily removable in a workshop, after disconnection of cables and fixings without the need to disturb the axle.

5.9.3 Calculations indicating the natural frequency of the motor suspension system shall be submitted, and shall clearly indicate that resonance with the bogie frame is avoided.

#### 5.10 Gearbox and Coupling

5.10.1 Contractor shall provide flexible coupling between traction motor and drive gear.

5.10.2 The gearbox shall be compatible with the flexible single stage/double stage coupling. The motor and the gearbox shall be proven for the proposed gear ratio selected by the Contractor. Gearbox movement shall be restrained by a torque reaction link between the gearbox and bogie frame. A safety device shall be incorporated to restrain gearbox rotation should the link fail in service. The gears including bearings shall not require overhaul at least earlier than 1.2 million kms. No sensor shall be installed in the gear case. Comprehensive, flexible and fully automatic test bench(s) shall be provided to test an overhauled/newly assembled gear case with transmission arrangement and duly mounted on the wheel set. The specification shall be got approved from the Engineer.

5.10.3 The gears shall be splash oil lubricated and a sight glass shall be provided in the gear case for inspection. It shall not be necessary to change the oil earlier than 200,000 kms. The sight glass shall be of prismatic or better. Suitable arrangement shall be provided in the gear case to trap magnetic impurities in the gear case lubricant.

5.10.4 The gearbox shall be subjected to a test based on the actual duty cycle on a specified Corridor with the specified torque and speed conditions. Testing shall start with gearbox at temperature of at least 46°C and temperature shall be continuously monitored. The temperature shall not exceed the manufacturer's recommendations consistent with life between oil changes. Test shall be carried out in both the directions. Noise and vibration test shall also be performed along with this test. The Contractor shall submit a Test Procedure based on international practice for approval by the Engineer.

5.10.5 The RPM considered for design and testing shall conform to maximum design speed with fully worn wheels.

5.10.6 The torque value considered for design of gears and coupling shall correspond to maximum tractive effort requirement for worst duty cycle. The torque value shall be taken with new wheel diameter. The temperature for type test shall be taken as 46°C i.e. ambient + 10°C proximity effect. The design value of gear box drive and coupling shall correspond to high tractive effort mode of operation and the design shall conform to the requirements of ERTS clause 3.22.7, 3.23, 8.1.9 and 8.9.9(iii).

#### 5.11 Wheels, Axles and Axle-boxes

5.11.1 The wheels shall be monobloc-forged steel, complying with the requirements of UIC Code 812-3/EN 13262, grade R8 (for 1435 gauge) having the hardness value of 250-320BHN or equivalent international Standard. However final selection of the grade shall be based on suitability for the type of brake system proposed and the head hardened rails used by the Employer and shall be decided during design review.

5.11.2 The powered axles shall comply with UIC Code 811-1/EN 13261

5.11.3 The non-powered axles shall comply with UIC Code 811-1/EN 13261

5.11.4 Wheels, axles, drive gears and axle bearings shall be assembled on axles by interference

5.11.5 The wheel tread shall be of the wear adapted wheel profile in accordance with RDSO sketch no. 91146 (Appendix-TH). Wheel Profile Measurement Gauge (mechanical as well as non contact laser guided Calipri tool or equivalent with accessories, to be finalized by Engineer during Pre-Final Design Stage) with tolerance of 0.1 mm shall be supplied for each depot. The cost of these tools shall be deemed to be included in the quoted price.

- 5.11.6 The Contractor shall furnish the extreme maintenance limit for wheels. The maintenance limits for wheels shall be within limits recommended in UIC 510-2 OR and SOD adopted by Engineer.
- 5.11.7 Axle bearings shall be of a proven type. The roller bearings shall have a minimum life rating of 3 million kilometers when computed in accordance with the method given in ISO 281/1. The Contractor shall provide adequate training to the Project Owner's Maintenance Personnel for overhauling of the axle bearings and shall also provide two sets of the special tools required for overhauling in each depot. The cost of such tools shall be deemed to be included in the quoted price. Details to be finalized during design stage.
- The passenger load as described in Clause 5.6.4 shall be taken for the design of the wheels, axles and axle bearings. Bearings shall be arranged not to carry any traction return current.
- 5.11.8 Natural frequencies of the wheels, axles, axle boxes and other un sprung equipment shall have sufficient separation between natural frequencies with the track structure to avoid resonance.
- 5.11.9 Wide range of lubricants with different characteristics is already available in India. Use of any of these lubricants, especially those which have performed well in similar uses is preferred. In case the Contractor proposes to use other lubricants, he shall simultaneously evaluate the characteristics of lubricants available in India and indicate the equivalent lubricant that can be used for maintenance.
- 5.11.10 Squeal noise shall be measured for at least one sharpest curve by placing microphone at 7.5m distance from rail centre at 3.5m height from rail top toward the direction of both inner rail and outer rail at elevated section (beyond the parapet wall by fixing the microphone on suitable height pole/mast etc.) or at grade, with normal vehicle operating conditions (i.e. TOR, WFL, Wheel Dampers as available in operating condition) including all installed assets, environmental and track conditions as per ISO 3095 at normal operational speed. Sound measuring time shall be the train pass by time (from train head passing time to train tail passing time) as per ISO 3095. A squeal noise shall be evaluated on basis of tone to noise ratio method/prominence ratio method as per Annex A of ANSI S1.13-2005.

5.11.11 Deleted.

5.11.12 Contractor shall provide at least one system each in each of the Depots for the automated wayside wheel profile measurement and temperature monitoring of axle box bearing. The cost of these systems shall be deemed to be included in quoted price. Details shall be finalized during design stage.

## 5.12 Bogie Brake Equipment

5.12.1 Tenderer shall provide Tread Brake units in all cars. Appropriate Provision shall be made to minimize Rail Contact fatigue incidences (RCF) and consequential need for reprofiling. Wheel reprofiling shall generally not be required below 0.25 million Kms on account of RCFs.

The Tenderer shall submit detailed comprehensive proposal on the Brake system along with the proof of provenness for similar metro applications and shall also include operator's comments on the proposed system.

Full details of the braking scheme are given in Chapter 6.

## 5.13 Automatic Train Control (ATC) Equipment Mounting

5.13.1 Full details of the Automatic Train Control System interface issues are given in Appendix TD.

## 5.14 Wheel Flange Lubrication (WFL) Equipment

5.14.1 Oil type Wheel flange lubricators of a proven design in EMU/ metro application shall be provided only at both driving ends of each train or Dry type Wheel Flange Lubricators on 50% axles of each train. The final decision shall be taken during design stage. A suitable mechanism shall be provided to ensure that lubricators operate only in the leading position on the train actuate suitably during traversing of the curves automatically and shall be effective for all wheels, the purpose of the WFL shall be to reduce wear of wheel and track/rail and reduce noise in the curves.

5.14.2 The design of WFL system shall ensure precise & cyclic application of lubricant on the flange of the wheel(s) so that the lubrication application is uniformly distributed on the flange surface without any excess deposition on the contact surface. There shall be no flow of lubricant on the tread/braking surface under any circumstance. The system shall be designed to minimize oil and air consumption.



Single tube system shall be preferred. The nozzles shall be designed to protect against choking /clogging due to dust. There shall be no movable part in the nozzle. The design shall permit optimized control of oil spray in straight and curved track by suitably modulating the spraying cycles and quantity of oil in the spray. The spray cycle as above shall be programmable and shall be fine tuned during field trials and performance of wheels during DLP. The programming tools shall be supplied to Employer (one set each line).

5.14.3 The spray of oil shall be time controlled as well as distance controlled. The actuation and spray cycle and quantity shall be decided by the location and degree of the curve which shall be communicated to the system by a centrifugal force sensor, coordinates and parameters of curves informed by the vehicle or/and through GPS. Status of WFL shall be available in TCMS. It shall be possible to isolate the equipment through TCMS in case of any defect/malfunctioning.

5.14.4 Provision shall also be made in bogies to permit fitment of dry type flange lubricator on 50% axles in a train. The complete arrangement shall be provided by the Contractor. The cost of the stick shall be borne by Project Owner/Employer. Details shall be discussed during design and got approved from the Engineer.

#### 5.15 Maintainability

5.15.1 Arrangements shall be made to exchange wheel sets with the minimum dismantling of bogie components being required. The procedure for dismantling shall be furnished.

5.15.2 The arrangement should allow the bogie to be mechanically disconnected, permitting the body to be lifted sufficiently far to provide access between body and bogie to disconnect traction motor cables, brake system flexible pipe connectors, and secondary suspension leveling valve linkages, etc.

5.15.3 The bogie frame shall have a suitable arrangement for lifting the bogie frame from the wheels and for lifting the complete bogie during maintenance in the workshop. Restraints to prevent loading of axle, primary suspension etc. in case of lifting by cranes/railments of the cars by jack or any means shall be provided. Dampers shall not get loaded/damaged in this exercise. The Contractor shall provide necessary restraint.

5.15.4 Body to bogie connection shall be easily accessible to facilitate exchange of bogies.

5.15.5 The target interval between bogie overhauls shall be not less than 1.2 million kilometers of service operation. The Contractor shall furnish inspection, maintenance and operational schedule of the bogies along with the intervals.

The bogie shall provide easy and safe access for all maintenance, including access for train operator to operate the isolating cocks for bogie-mounted equipment and parking brake manual release.

The Contractor shall submit the detail of ultrasonic testing of powered & non- powered axles. The detail shall include the testing procedure and pattern used as reference for this test, which shall be used by Employer's maintenance staff/personal.

5.15.6 The bogie frame shall be fitted with suitable locations for lifting off the wheels and axles, for lifting the complete bogie frame during maintenance in the workshop and for re-railing a car or bogie. Jacking pad location shall be provided to match the shop equipment during the design stage.

5.15.7 In addition, the design of the bogie frame shall incorporate horizontal and vertical pads at diagonal positions for re-railing operations following derailments.

5.15.8 Re-profiling on an under-floor wheel lathe shall be often performed in remote workshops without dismantling parts.

5.15.9 The bogies shall be capable of being cleaned using high-pressure hot water or steam jet cleaning equipment, with or without detergents. All closed sections and pockets shall be self draining or sealed against water ingress. All bearings shall be adequately sealed to ensure that water and cleaning fluids do not enter during the cleaning process.

5.15.10 Bogies shall be capable of being disconnected and reconnected easily and with a minimum of operations by personnel working in pits or alongside the bogies. It shall be possible to easily inspect for correct reconnection without the need for special tools or instruments.

5.15.11 It shall be possible for personnel working in pits or alongside the bogie to visually inspect the condition of bogie components, such as brakes and wheel treads, easily and without the use of special tools

**5.16 Deliverables**

5.16.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	5.11.5	Wheel Profile Measurement Gauge	For each depot
2.	5.11.7	Special tools for overhauling of the axle bearings.	Two sets in each depot.
3.	5.11.12	Tools for the wayside wheel profile measurement.	At least one tool each in each of the depots.
		Tools for the temperature monitoring of axle box bearing.	
4.	5.14.2	Programming tool for spray cycle of WFL System.	One on each line.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



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**6. PNEUMATICS, AIR SUPPLY AND BRAKE SYSTEM****6.1 General**

6.1.1 Each 3 car unit shall be fitted with a complete "stand-alone" compressed air supply system. In case the train configuration is changed to 8 car (if required), the compressor of one 3 car unit shall be capable of catering the compressed air supply requirement for additional (T+M) unit also.

6.1.2 The Pneumatic and Air Supply System (See Clauses 6.2 to 6.12 inclusive) shall consist of, but need not be limited to, the following:

- (i) Air compressor unit and 3-phase 415V induction motor drive
- (ii) Auxiliary Compressor and 110V DC motor drive
- (iii) Air drier and filtration components
- (iv) Reservoirs
- (v) Pressure governors and switches
- (vi) Pipe system
- (vii) Air suspension equipment
- (viii) Automatic coupling actuating equipment
- (ix) Pantograph actuating equipment
- (x) Ancillary pneumatically driven devices.

6.1.3 The Brake System (See Clauses 6.13 to 6.22 inclusive) design shall be subject to review, and shall consist of, but need not be limited to, the following:

- (i) Electro-pneumatic friction brake system (EP)
- (ii) Electric-regenerative brake system
- (iii) Provision of smooth and continuous blending of EP and regenerative braking
- (iv) Spring applied air-release parking brake system
- (v) Electro-pneumatic friction emergency brake system
- (vi) Extended EP and Emergency brake during rescue operation. Refer ERTS 6.20
- (vii) Wheel spin and slide protection
- (viii) Microprocessor based brake control system
- (ix) Emergency brake push buttons.

**6.2 Air Compressor and 3-phase 415V induction motor Drive**

6.2.1 The compressor and associated pneumatic equipment shall be so positioned as to facilitate access for maintenance and ensure freedom from noise, vibration and discomfort to passengers and train crew.

6.2.2 Reciprocating air compressors proven in EMU metro operations for at least 2 years, operating from a 415V 3-phase 50 Hz power supply with an adequate free air delivery capacity for three-cars shall be provided. One compressor shall have sufficient capacity to charge a completely empty six-car train including full air suspension inflation within 30 minutes. The average duty cycle of each compressor without electric braking shall not exceed 45% during operation. The Contractor shall submit calculations to show that the capacity of the compressor will meet the worst conditions.

6.2.3 In the event of total failure of electric brakes and one air compressor on a fully loaded six as well as eight car train, the remaining air compressor on the train shall have sufficient capacity to enable the train to remain in service for at least four (4) hours. An "intelligent air compressor management" (with option of forced start) shall be provided to ensure that both the compressors on a six as well as eight car train are operated during fill-up and both the compressors in the train are operated alternatively thereafter, to avoid moisture condensation in the compressor due to low duty cycle.

6.2.4 The Contractor shall convincingly establish that the reliability and maintainability of the compressor offered, has been established in actual EMU metro service. The Contractor shall, inter-alia, submit letters from actual users indicating experience with the compressors on their system.

- 6.2.5 The motor compressor unit shall be a compact unit consisting of compressor, motor drive, coupling and inter and after cooler, resiliently mounted to minimise the levels of vibration transmitted to the car body.
- 6.2.6 The intake air shall be directed through a properly designed filter, suitable for the dusty atmospheric conditions prevailing in Mumbai. Filters shall be easy to clean and shall be easily accessible for cleaning and replacement. Since dust & humidity protection of the intake air is very crucial, specific measures shall be taken to ensure under no circumstance the dust/moisture enters in the compressor.
- 6.2.7 A pressure switch shall control the cutting in and out of the compressor.
- 6.2.8 Safety valves shall be provided to protect the system from over pressure.
- 6.2.9 A non-return valve shall be provided between the compressor and the main reservoir supply line.
- 6.2.10 The compressor shall not be made to start against back pressure. A soft start feature as a built in part of SIV or direct on line shall be provided.
- 6.2.11 The drive motor shall conform to the requirement of IEC 60349-2 and the temperature rise of the windings of the motor shall be limited to temperature index of the insulation minus 70° C. The motor shall have at least IP55 protection.
- 6.2.12 The Contractor shall by calculations or otherwise establish that the compressor will meet the above conditions.
- 6.2.13 The compressor shall be designed to achieve a minimum of 12000 hours of running time between overhauls. Routine maintenance shall not be required at a frequency more than once per year.
- 6.2.14 Correct functioning and running hours of compressors shall be monitored and recorded by TCMS.

### 6.3 Auxiliary Compressor

- 6.3.1 A proven 110V DC operated compressor (oil free) shall be provided for operation of pantograph and VCB during start-up of the train. The compressor shall work satisfactorily within voltage range of 77V to 138V DC Minimum protection class should be IP 55.

### 6.4 Air Dryer and Filtration

- 6.4.1 The air delivered to the pneumatic system shall be clean and dry and shall conform to the air quality specified in ISO 8573. An air dryer and filtration unit proven on rolling stock application suitable for extremely hot, humid and dusty conditions prevailing in Mumbai, shall be provided.
- 6.4.2 The grade of filtration at rated pressure shall be minimally as follows:
- |       |  |   |               |
|-------|--|---|---------------|
| (i)   | Particles removal down to                      | : | 1 micron      |
| (ii)  | Liquid water removal                           | : | > 95%         |
| (iii) | Dew point depression at 10kg/cm <sup>2</sup> : |   | minimum 25°C. |

The Contractor shall advise percentage relative humidity of outlet air. However, the relative humidity at the outlet of the air dryer shall not be more than 35%. Air dryer design shall ensure that under all ambient conditions prevailing in Mumbai, no condensation takes place.

- 6.4.3 A proven regenerative type of air dryer using desiccant and of a suitable capacity shall be provided between the air compressor and the main reservoir. The air dryer shall be preceded by an automatic drain valve, which collects and discharges the bulk of the moisture in the compressed air, before it enters the air dryer. The air dryer shall have IP65 protection.
- 6.4.4 Suitable means of dust separation, along with automatic drain valve prior to the air dryer shall be provided. An inter-cooler and after-cooler of liberal capacity shall be supplied to ensure efficient operation of the air dryer. A humidity indicator showing the condition of the outlet air through change of colour shall be provided. Full technical details of the proposed air dryer shall be furnished by the Contractor for review by the Engineer. Interval for replacement of desiccant in the dryer unit shall be furnished.
- 6.4.5 All failures of the air dryer shall be displayed in the TCMS/OCC

### 6.5 Reservoirs

- 6.5.1 Main reservoirs with adequate capacity shall be provided on each three-car unit to distribute the air to various systems. The reservoirs shall incorporate a safety valve and an automatic drain valve. The Contractor shall provide calculations to substantiate correct sizing of the reservoirs.



- 6.5.2 The brake service reservoir shall have sufficient capacity for three consecutive full service brake applications with a train speed of 80 kmph fully loaded. This shall be achieved without electric brake supplement and without air replenishment from the main reservoir.
- 6.5.3 Reservoirs shall be manufactured from stainless steel. All reservoirs shall have a device for venting and draining of the contents of reservoirs. All Reservoirs shall conform to the requirements of EN 286-3:1994.
- 6.5.4 Separate reservoirs of suitable capacity shall be provided for satisfactory operation of other on-train pneumatic systems.
- 6.5.5 Reservoirs shall be provided with manual draining arrangement which shall normally be automatically locked and secured.
- 6.6 **Pressure Governors and Switches**
- 6.6.1 Pressure governors and switches proven in EMU metro applications shall be provided for various control and monitoring functions.
- 6.7 **Pipe System**
- 6.7.1 A main reservoir pipe shall run continuously throughout the train.
- 6.7.2 All piping shall be of stainless steel conforming to the requirements of Duplex Steel or equivalent with flare less bite type double compression fittings generally conforming to the requirements of DIN 2353.
- 6.7.3 Sharp bends shall be avoided and standard connections shall be used as far as possible. All pipe lines shall be suitably colour coded. The proposed colour coding shall be reviewed during the Under Frame Equipment Layout Mock-up review.
- 6.7.4 All branches from the main reservoir pipe or control system shall be fed via self-locking cocks (coloured according to the corresponding pipe colour) with or without vent and electrical switches as appropriate. Magnet valves, reducing valves, check valves, silencer and drain plugs etc. shall be incorporated as required.
- 6.7.5 Quick release coupling test points made of stainless steel, with blanking plugs shall be provided. They shall be located in easily accessible positions.
- 6.7.6 Flexible hoses shall be kept to a minimum, and be proven in EMU metro service. Burst hose protection shall be provided to increase the integrity of the air supply system against rupturing of inter-car flexible hoses. Armoured hoses shall be provided in the flexible connections in the parking brake piping.
- 6.7.7 Foreign matter shall be removed from all pipes prior to installation.
- 6.7.8 Deleted.
- 6.7.9 All pipes shall be installed by means of clamps with integral, moulded vibration damping inserts to prevent any rattling in service. Clamps shall not be welded to the pipe.
- 6.7.10 Where piping pass through holes in the floor, structure member etc. it shall be rigidly clamped immediately adjacent to the hole to prevent contact to the edge of the hole.
- 6.7.11 In the event of leakage from the Pneumatic circuit/system, it shall be possible to isolate the effected part of the circuit by train operator (remote isolation during GoA3/GoA4) and reach up to destination station. Isolation arrangement shall be simple and shall not require more than square key normally carried by Train Operator. Contractor shall submit detail plan during design for engineer's approval. The isolation arrangement shall preferably be in the saloon and shall be secured and monitored alternatively the isolation arrangement may be through magnet valves.
- 6.8 **Pressure Gauges**
- 6.8.1 All driving consoles shall be fitted with analogue pressure gauge with life of more than 15 years which indicates:
- (i) The pressure in the main reservoir pipe.
  - (ii) The pressure in the brake reservoir and brake cylinder pipe.
- 6.8.2 On all cars, test points, onto which test gauges may be connected, shall be provided in the vehicle brake and air supply system. The location of the test points shall be reviewed by Engineer and shall be demonstrated during the review of Underframe Equipment Layout Mock-up. The tests points shall be provided, at the minimum, to measure the pressure of the following:



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- (i) Compressor motor governor
- (ii) Brake cylinder pressure
- (iii) Main reservoir pressure
- (iv) Parking brake pressure
- (v) Brake service reservoir pressure
- (vi) Deleted
- (vii) Overflow valve
- (viii) Air spring pressure
- (ix) Any other point, which in the opinion of Engineer is required.

#### 6.9 Levelling Valve System

6.9.1 A leveling control system shall be provided to ensure transversal control of body height under all conditions of load. In each bogie, one leveling system shall be provided to adjust air pressure in the air springs. In the case of failure of one air spring, the other should quickly bleed out so that the carbody is lowered to its stable position. The air supply for the leveling system shall be taken from the main reservoir pipe and a separate reservoir shall be provided with each air suspension bellow. However, an alternate proven design meeting the functional requirements may be proposed by the Contractor for approval of the Engineer. Load sensing valve shall be provided. Antiroll bars shall be provided with air suspension units.

6.9.2 Levelling valves shall be installed as far as possible outside the wheel in the bogie so that the dynamic load changes are addressed appropriately.

#### 6.10 Front Automatic Coupling Actuating Equipment

6.10.1 Control of front auto coupler for rescue operation shall be from the driving console. The Isolating cocks for MR for extension of air supply through the coupler shall be located in the driving console. Any other operation required necessary for coupling shall be from the driving console only. There shall be a provision to connect the two trains to facilitate communication between the two trains.

#### 6.11 Ancillary Pneumatic Devices

6.11.1 Pantograph actuating equipment shall be fed by air supplied from an auxiliary reservoir, suitably located in each unit with auxiliary compressor, for the purpose of initial raising of pantograph and closing of VCB.

#### 6.12 Isolation of Defective Equipment

6.12.1 Isolating valves and switches shall be provided to enable parts of the system to be isolated.

6.12.2 All isolating valves that require operations by train crew in normal operation or in emergencies shall be easily accessible either from within the car or from track level as appropriate. The location shall be finalized during Pre-final Design Stage. The isolating valves shall be colour coded.

6.12.3 Isolating cock handles shall lie parallel to the pipe in which it is installed, in the normal operational (Open) position, and perpendicular to the pipe in the isolated (Closed) position, and shall operate in the horizontal plane only. Cable ties shall provide a ready means of identification of a cock, which has been operated.

#### 6.13 Brake System

6.13.1 The brake system and components shall be proven, state of art and widely used in modern metro rolling stock. The brake components, valves etc. shall have been in use and have established their satisfactory performance and reliability on at least three mass rapid transit systems in revenue service over a period of last three years or more (in each MRTS) outside the country of origin in three different countries or in an MRTS in India. The options for brake system have been specified in clause 5.12.1. Train braking performance shall be as specified in Chapter 3, Clause 3.22.1 and shall be designed for 90 kmph. The operational speed shall be 80 kmph. The system shall generally conform to EN13452.

Brake valves shall be designed and validated for heavy duty cycles required for intensive brake blending. No change of valves or components except rubber items shall be required for at least 15 years beyond DLP. Contractor shall assess the cyclic load under worst service conditions appearing together and validate the same on a test bench.

6.13.2 The brake system shall be complete in each three-car unit, and shall consist of:



- (i) An electro-pneumatic friction brake system (EP).
- (ii) An electric regenerative brake system.
- (iii) Provision of smooth and continuous blending of EP and regenerative braking.
- (iv) A spring applied air-release parking brake.
- (v) A fail safe, electro pneumatic friction emergency brake system.
- (vi) Extended EP & Emergency brake during rescue operation. Refer ERTS 6.20
- (vii) Emergency brake push buttons
- In case of addition of one (T+M) unit (if required), the brake system of additional unit shall interface with that of 6 car train to meet the braking performance requirement of complete train.
- 6.13.3 The EP brake shall be so designed that its control function can be taken over by the other redundant control elements in the case of failure of individual electronic or electrical control elements.
- Redundant power supply and processor card for hot stand by in the control unit and spare slots for I/O cards shall be ensured. However, any other suitable design for redundancy of EP Brake control function may be proposed by the Contractor subject to approval of the Engineer.
- 6.13.4 The friction braking shall be achieved by bogie mounted brake actuator units operating on the EP system. The EP service and emergency brakes shall be applied by the same brake actuators.
- 6.13.5 Roll Back protection shall be provided to ensure that the train moves only bare minimum standing on gradient with power on. The direction of wheel movement with respect to master controller position shall be compared and protection shall be applied in case of conflict.
- 6.13.6 The friction brake system shall be proven and capable of independently achieving all performance requirements for a continuous round trip with maximum speed of 50Kmph with AW2 load case without the aid of electric braking.
- 6.13.7 When a train is at standstill there shall be sufficient retention of brakes (holding brake) such that the train does not roll back on a 4% gradient. The brake application shall be retained while traction power is applied and the train takes forward movement.
- Specific provision shall be made in the software to ensure that the train safely starts on the gradient, the roll back if any is nominal.
- 6.13.8 It shall be possible to isolate the friction brake system individually on each bogie. The isolation device [Bogie Isolation Cock (BIC)] shall be located inside the passenger saloon area (duly protected by a lockable cover) and also on the under frame adjacent to the bogie (either side) and be readily accessible. The isolation shall be readily discernible to operation and maintenance staff and shall be displayed on HMI. Isolation of any bogie shall popup an alarm in TCMS VDU/OCC for information and acknowledgement in both operation mode as well as in maintenance mode. The isolating cock for leading Bogie for DM car shall be in the Driving console. For all other bogies, it shall preferably be in the cubicles. Contractor shall also refer ERTS 6.7.11 during design of isolation arrangement. Separate magnet valve shall be provided for remote operation to isolate the friction brake system individually on each bogie.
- 6.13.8.1 In case of isolation of bogies, a suitable speed restriction shall be applied in compliance with Metro Railways General Rules (MRGR).
- If no. of bogies isolated is more than the minimum bogies required to achieve Guaranteed Emergency Brake Requirement (GEBR), then traction block shall be applied. However, it shall be possible to override the traction block and a speed restriction of 10 kmph (configurable) shall be applied. Speed restrictions shall be finalized during design stage.
- 6.13.8.2 In case more than 50% bogies are isolated in a train, then the traction block shall be applied and it shall not be possible to override the traction block.
- 6.13.9 If due to any reason parting of train is being perceived without actual taking place, the emergency brakes of the portion of the train which perceived parting shall automatically get applied. It should be possible to move the train further by isolating the bogie brakes of this portion of the train. In such situation, the control system shall automatically impose restriction on the maximum speed. The level of the speed will be decided during the design stage.
- 6.13.10 All devices capable of isolating a portion of the brake system shall be located and protected to avoid inadvertent or malicious operation. The operation of such isolation device shall be clearly visible to maintenance staff once operated.

- 6.13.11 Brake friction materials shall not contaminate the tracks and other underframe mounted equipment adversely so as to affect train detection by the Signalling System.
- 6.13.12 Brake pads shall be of composite material and shall contain no toxic material. Heating by the brake pad shall in no case cause any damage to the wheel tread.
- 6.13.13 The brake pad shall be proven in EMU metro application. The friction characteristics of the brake pad material shall be tested on brake dynamometer, in both dry and wet conditions in the range of 0-90 kmph under various designed brake forces. The test scheme and acceptance criterion shall be submitted for review by the Engineer. The Tenderer shall furnish brief description of the proposed brake system along with the expected life of brake pads based upon experience of other Metro Railways.
- 6.13.14 The Brake calculations under all the service operating conditions including wheel-rail interaction study, adhesion calculations and for emergency braking distances under dry and wet conditions shall be submitted. Braking distances for normal service braking with electric brake blending shall also be submitted.
- 6.13.15 All the pneumatic control equipment and valves for one car shall be mounted in the enclosed lockable boxes, made of stainless steel/Aluminium (anodized).
- 6.13.16 The air supply and distribution systems shall be arranged such that any single type failure can be readily isolated such that full performance capabilities are maintained.
- 6.13.17 Deleted.
- 6.13.18 It shall be possible to test the functioning of brake system while at standstill at depot or at termination station.
- 6.13.19 The system shall provide adequate protection against brake binding and give indication to the TCMS/OCC.
- 6.13.20 Following minimum SIL levels at train level shall be complied for the brake system

Emergency brakes	SIL 3
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The contractor shall submit relevant certifications for the SIL levels as above.

- 6.13.21 The speed measurement devices and couplings required for measurement of train speed in a fail safe manner by the Signaling and Train Control Contractor shall be installed on one non powered axle in each 3 car unit (DM+T+M) which shall be:
- Not used for service brake application and;
  - Used for emergency brake application, whenever required.

This shall be finalized by the Contractor during finalization of interface with signaling Contractor. In case signaling Contractor is not yet finalized by Employer then the design shall be finalized in consultation and with the approval of the Engineer.

The train braking system shall meet the specified braking performance requirements with the above considerations.

#### 6.14 Electric Regenerative Brake and Electric/Pneumatic Brake Blending

- 6.14.1 Priority shall be given to the electric regenerative brake whenever a brake command is initiated. The electric regenerative brake shall also be load weighed to ensure consistent performance. The use of electric regenerative brakes shall be maximized in all service braking modes, and shall make full use of the adhesive weight on all motor car axles.
- 6.14.2 Brake blending logic shall ensure priority of electric regenerative braking over pneumatic braking. If the demanded brake effort is not achievable solely by the electric regenerative brakes, the pneumatic brake system on the T cars shall provide supplementary brake effort. The Contractor shall submit full proposal for review. Electric regenerative brake fade out shall not occur above 5 kmph. For the given Brake demand signal, the Brake effort achieved shall be same during the transition from ED to friction Brake. After the speed is reduced to a very low speed, holding brakes shall be applied to prevent the train from rolling backwards at station stops and gradient.
- 6.14.3 The electric regenerative brake shall be independent for each Motor Car and faults on one car should not adversely affect the braking performance on the other. Each Car shall have independent Brake Electronics with wheel slide control.



- 6.14.4 In the event of failure of electric regenerative brake or during fading, the friction brake shall be capable of carrying out full braking duty. Smooth and safe changeover from regenerative to EP brakes in case of failure of regenerative brakes or during fading shall be ensured.
- 6.14.5 The Contractor shall submit brake effort vs. speed characteristics showing the contribution of regenerative braking and electro-pneumatic braking separately over the entire speed range and at different loading conditions of the cars.
- 6.14.6 Deleted.
- 6.14.7 Regenerative braking shall be actuated and applied only in the event of the train exceeding the set speed (settable between 20 to 35 kmph) since last stop. For train speed up to the set speed since last stop, only friction brakes shall be applied.
- 6.15 Parking Brake**
- 6.15.1 Parking brakes shall be incorporated on 50% or more of brake actuators of DM, T and M cars. Parking brakes shall be capable of holding a fully loaded stationary train on a 4% gradient under all track conditions, indefinitely. Inadvertent/unintended application of parking brakes due to air leakage or otherwise will be detected and displayed on TCMS as fault indication. It shall be possible to isolate the parking brake unit and release the traction interlock. The control of parking brake shall be through hardwire.
- 6.15.2 Parking brakes shall be applied in the event of loss of the main compressed air supply. The parking brakes shall be capable of release from within the driving console when the compressed air supply is present. With no compressed air supply available, it shall be possible to release individual parking brake actuators manually from saloon or from platform level. Application of parking brakes shall also be controllable from the driving console and remotely from OCC. The design shall be such that the parking brakes will take effect prior to fade off of service brake and shall ensure that the combined brake effect of the pneumatic brake and parking brake is never less than the full brake effort of the parking brake alone. Parking brakes shall be directly actuated by MR pressure.
- 6.15.3 Status of train parking brake shall be displayed in the active driving console and remote control centre.
- 6.15.4 In the event of air leakage from the air feed to parking brake/within the unit and consequential application of parking brake/traction block, arrangement shall be provided for isolation and manual release of Parking Brake(s) so that traction block is released and train is operable as usual. The parking brake manual release arrangement shall be provided in each car or at platform level and it shall not be accessible to the passengers. If manual release arrangement for parking brake is provided at platform level then special tools shall be provided for accessing it from platform level when train stops at any position with respect to Platform Screen Doors (PSD). Two (2) no. of such tools shall be provided in each train. Separate Isolating cocks (PIC- Parking Isolation Cock), adjacent to the Isolating cocks (BIC) shall be provided in each car. For DM cars, these shall be in Driving Console. No traction block shall occur on account of parking brakes, after the same has been isolated.
- 6.15.5 Deleted.
- 6.16 Emergency Braking**
- 6.16.1 Emergency braking shall be applied by de-energisation of an emergency magnet valve as a consequence of brake in emergency brake loop wire. The break can be caused by the Train Operator intentionally or by opening of contacts of safety devices in the brake loop, provided in the design, to avoid unsafe conditions. Two brake loops shall be provided; one normal and the other redundant. Both brake loops shall be controlled by separate feeder MCB.
- 6.16.2 Emergency brake is applied by friction brake system. Electric regenerative brake shall be isolated during emergency braking. The Emergency braking shall be load weighed. Emergency braking rate as specified in clause 3.22 shall be achieved from 80 kmph to 0 kmph up to fully loaded train on level tangent track.
- 6.16.3 Emergency brake push-button shall be installed in each driving console in the train. Activation of the buttons, shall apply the emergency brakes under all conditions. Movement with Emergency push button activated shall be possible only after by passing the Brake loop with a cutout switch provided in the driving console(s). Activation of the EPB shall not result in opening of VCB and /or lowering of Pantograph.

In the event of mal-operation of emergency brakes from working driving console, it shall be possible to operate train from either driving console (to be decided during design) in either direction at restricted speed.

- 6.16.4 Parting of the train shall result in an emergency brake application on both halves of the train.
- 6.16.5 Wheel slide protection shall be available during emergency braking. Any failure in the wheel slide protection in emergency braking shall result in the application of full brake force and deactivation of the slip/slide system.
- 6.16.6 Activation of the emergency brake by any means shall result in the propulsion system being disabled in a safe critical manner. The Emergency condition shall not get reset till the train has achieved zero speed (i.e. train at stand still). The propulsion system shall not be re-enabled until the train is at zero speed and the emergency condition has been reset.
- 6.16.7 The Contractor shall furnish emergency braking distances to standstill, for a fully loaded train from speeds, starting from 10 kmph to 80 kmph in increments of 10 kmph.
- 6.16.8 The friction brake system shall be rated to, and have sufficient thermal capacity to safely complete two successive acceleration and emergency brake cycles, with no interval between each cycle. Each cycle shall comprise a full acceleration from standstill to 90 kmph followed by the application of emergency brake to standstill. On the completion of the two cycles, the brake system shall show no abnormalities. The requirement shall be demonstrated during testing.
- 6.16.9 The Contractor shall furnish the maximum braking distance from a speed of 80 kmph to stop, under emergency brake application. The guaranteed maximum braking distance shall satisfy the requirements specified in table 15.1.B emergency brake application. The guaranteed maximum braking distance shall satisfy the requirements specified in table 15.1.B emergency brake application.
- 6.16.10 The Contractor shall provide the guaranteed emergency brake de-acceleration rate to signaling Contractor during interface. The Guaranteed Emergency Brake rate shall be decided on the basis of minimum initial adhesion of 6% on the Mumbai Metro network, one car brake isolated and with maximum 15% emergency brake distance extension (for adhesion from 8% to 6%) due to wheel sliding.
- In case of adhesion being below 6% and actual emergency brake rate is found lower than the guaranteed Emergency Brake Rate, it shall be the Contractor's responsibility to prove to the satisfaction of the Engineer that the initial adhesion is below 6%. For determining the adhesion, UIC 541 shall be followed. The system diagnostic shall record all relevant signals and shall be retrievable for analysis. The necessary software/hardware tools shall be given to each depot.
- 6.16.11 Complete friction brake system shall be tested on Brake dynamo-meter and validated during field tests.

#### 6.17 Brake Control System

- 6.17.1 A high integrity fast response closed loop digital brake control system shall be provided with the brake regulation rate at  $\pm 5\%$  of the deceleration demand. The closed loop is formed by the dynamic brake and the pneumatic brake: use of dynamic brake is maximized, achieved dynamic brake information is provided to pneumatic brake control, and this control applies to the remaining need of brake in order to reach the total demand. The Contractor shall ensure that the brake system is so designed that failure of any single control component shall not result in loss of braking performance of the train. All circuits and controls essential for braking equipment shall be a fail safe, double break circuits, and shall have high integrity 'hard wire' feeds and inputs. These feeds and inputs shall be duplicated. A microprocessor based brake control system shall be offered.
- 6.17.2 The Contractor shall submit the details of the brake control system interfaces with the vehicle control circuits, The Propulsion system, the Master Controller, PWM generator/ Digital Control and ATP/ATO etc. The brake control system logic shall have adequate redundancy and back-up. PWM data from PWM generator or digital data and ATO shall be hard wired but shall also be received through TCMS as back-up. The system design shall also define the fall back mode operation when PWM data/digital data is not available from both the PWM generator/ Digital Control and TCMS back-up, because of any reason.
- 6.17.3 A Deadman device shall be incorporated into the Master Controller Handle. Activation of the same shall cause emergency brake application. Ergonomic Design of Master Controller shall ensure minimum strain on Train Operator's arm. Twist type Master Controller shall be preferred. Overall design shall specifically be got approved from Engineer.
- 6.17.4 A Load Weighing Signal, proportional to the passenger load shall be applied to the control systems for the rates of acceleration and braking, and for ensuring correct adjustment of the car body by the secondary air springs.
- 6.17.5 A sufficient degree of redundancy without adversely affecting system reliability may be used to



achieve the degree of fail-safe operational required.

6.17.6 The Brake control unit shall have provision for logging of selectable parameters/signals (by the Employer/Project Owner) and faults with related data. The memory shall be extendable. Provision shall be available for continuous logging or logging triggered by a particular event of User selectable parameters (up to 20 at a time) for a period of up to 24 hrs. The memory shall be adequate to store the above data including additional minimum 20000 incidents. Provision shall be available to download the stored data. Supply of any special tools complete with requisite software (one set for each depot) required for the above shall be included in the quoted cost. Training shall be organized by the OEM trainer in India for adequate duration before the commissioning of first 10 trains and cost of training is deemed to be included in quoted price of contract.

6.17.7 The diagnostic tools for brake system shall include complete graphical & analytical tools, recording of events, data of brake system and interface signals etc. It will also have facility to add on the necessary signals as requires during fault investigations.

#### 6.18 Jerk Limitation for Service Brake

6.18.1 The build-up of pneumatic brake force shall be jerk limited (for changes in brake demand) to increase passenger comfort. The jerk limitation is  $0.75\text{m/s}^3$ . This limit shall also be respected at the time of final stoppage also.

The Rolling Stock Contractor as well as Signalling Contractor shall comply EN 13452-1 or equivalent international standards for jerk determination and methodology shall be finalized during design stage with the approval of Engineer.

6.18.2 Jerk rate control shall be applicable to braking as well as propulsion.

6.18.3 Removal of power and application of brakes under emergency braking conditions shall not be jerk limited.

6.18.4 Removal of power and brake effort under wheel slip conditions shall not be jerk limited. The reapplication of power and brake effort shall be jerk limited.

#### 6.19 Brake Operating Timing

6.19.1 The following maximum brake operating timing shall be achieved on all cars of a train. The maximum time for a brake application from initiation of brake application command from BECU to 90% of full Brake Cylinder Pressure (BCP) and for brake release from initiation of brake release command from BECU to 10% of BCP shall not exceed the following:

- |       |                                     |   |             |
|-------|-------------------------------------|---|-------------|
| (i)   | Service Brake Application           | : | 2.0s        |
| (ii)  | Emergency Brake Application         | : | 1.5s (max.) |
| (iii) | Service and Emergency Brake Release | : | 2.5s.       |

The Contractor shall provide the timing diagram during design stage.

6.19.2 Any Malfunction of brake control system, which can cause an unsafe operation, shall result in an emergency brake application. In case of single point failure in brake control system, which can be automatically isolated and fully compensated without affecting the train performance, the application of emergency brake should be avoided.

6.19.3 Brake Assurance Time (the time from initiation of the brake application signal from TO/VATO, to achievement of the retardation rate requested), shall be provided. Full details shall be given. This feature will require close liaison with the Signalling Contractor.

6.19.4 In case, full compensation of brake control system is not available, the train control system shall impose a suitable speed restriction so that the braking distance is not exceeded.

#### 6.20 Brake control under rescue operation

During the rescue operation of pushing/pulling of a defective train loaded with passengers, the healthy train shall ensure simultaneous brake application in both healthy and defective train. Release of parking brake/holding brake of the defective train shall be possible from healthy train after mechanical and pneumatic connections.

For brake application purpose, the contractor shall:

Provide extension of EP brake and emergency brake lines from healthy train to defective train through a suitable jumper cable which can be connected manually during such eventualities. The

extended EP brake lines shall be in form of coded hardwires brake lines. The jumper connection shall be easily accessible, flexible and self lockable after connection. The connector housing shall have protection level not less than IP65 and shall be designed to automatically protect the connector against dust and water. The cover shall harmonise with the external finish. One set of jumper cable shall be kept in each driving console duly secured. The hardware lines as well as jumpers shall be with 100 % redundancy with one jumper connector on each side of the driving console front. The system shall ensure the integrity of these lines by built-in self test and also their isolation in case of extension of feed to the faulty brake lines of the defective train. Details shall be discussed during design stage.

#### 6.21 Failure Management

6.21.1 It shall be possible to recover a dead train (i.e. one having no traction power and no means of generating further compressed air, but with the air brake system intact) using only an air connection from the rescue train or locomotive. The emergency brake application of the dead train shall be possible by its operator. The detailed scheme shall be subject to the Engineer's review during design finalisation.

#### 6.22 Wheel Slide Protection (WSP)

6.22.1 Wheel slide protection with gradual slide correction shall be provided in all braking modes, on all cars. Slide detection and correction shall be on a per axle basis. The slide protection scheme provided shall be capable of detecting the severity of the slide and provide the appropriate level of slide correction.

6.22.2 The wheel slide system shall detect the onset of slide by (a) an axle deceleration exceeding a pre-set parameter, and/or (b) detection of a difference between the relative speeds of the axles. A proven speed sensor mounted on each axle shall be provided to detect the speed of associated wheels for implementing wheel slide protection scheme. Wheel slide indication shall be displayed through TCMS in the driving console. The Contractor shall submit full details of wheel slide protection scheme and equipment. Dump valves shall be monitored for their correct functioning and shall be monitored by TCMS. System shall ensure correct functioning of dump valves as pretest before train is dispatched from depot or initialized.

6.22.3 6-car train shall be subjected to complete type test as per UIC 541-05 and may have to be validated on more than two trains. Slide protection scheme shall include suitable measures for condition involving simultaneous slide in all 4 axles of any car.

The type test protocol shall be agreed with the engineer and shall be in line with ERTS 15.15.4.

6.22.4 Deleted.

#### 6.23 Monitoring

6.23.1 The performance of brake system shall be monitored by the Train Control & Management System (TCMS) and displayed in the train operator's driving console.

#### 6.24 Documentation

Contractor shall supply exhaustive documentation on complete pneumatic system, its sub systems and components, Brake electronics (hardware and software), project software details, explanation and functionality at component and system level, coloured schemes of pneumatic system, brake system, valves with coloured cut sections under different operational states. It shall also include trouble shooting and diagnostic details explaining clearly (with coloured illustrations) the logics, transition states, algorithms, signal flow and software parameters etc.

The contractor shall supply animation of complete pneumatic system, covering all pneumatic valve operations etc., demonstrating the complex pneumatic system for training purpose, which shall help in fault finding during maintenance period.

6.25 Engineer shall be able to adjust/change Brake cylinder pressure and other output parameters of Brake System. Any hardware/software tool required for this purpose shall also be provided. The documentation including but not restricted to flow charts (for complete software), signal flows, and interpretation of signal etc. shall be provided. Nominated Representative of the Engineer shall be fully trained and made fully conversant by the Contractor for this purpose.



**6.26 Deliverables**

6.26.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	6.16.10	The necessary software/hardware tools shall be given to each depot for determining the adhesion as per UIC 541.	To each depot.
2.	6.17.6	Supply of any special tools complete with requisite software as per clause 6.17.6	One set for each depot
3.	6.25	Hardware/software tool to adjust/change Brake Cylinder Pressure.	One set at each depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

## 7. DOOR AND DOOR CONTROL SYSTEM

### 7.1 General

7.1.1 Door system shall generally be compliant with EN14752:2015 or latest unless otherwise specified.

7.1.2 The train shall have following type of doors:

- (i) Passenger Saloon Door
- (ii) Front End Emergency Door
- (iii) Deleted
- (iv) Passenger Saloon to Driving Console Door
- (v) Passageway Sliding Door for 'First Class' Car.

### 7.2 Passenger Saloon Door

#### 7.2.1 General

- (i) Each car side shall have minimum four pairs of externally hung, sliding bi-parting doors. The clear door opening width of each door pair shall be minimum 1400mm and a clear height of at least 1900mm. The doors shall be electrically driven.
- (ii) The inner and outer skin of the door leaf shall be formed in such a way as to be lightweight, of adequate strength, and internally reinforced and formed into an integral unit, in such a way as to prevent injury to passengers or staff.
- (iii) Stainless steel Sheet metal of similar finish, as adopted for sidewall shall be of ample gauge to provide adequate strength and rigidity shall be used for outer sheet. Specific approval shall be obtained from the Engineer during design stage. Joints and edges shall be thoroughly sealed against ingress of moisture with drain holes located at the bottom of the doors to allow drainage of condensate. However, inside door leaf of Aluminium or stainless steel with matching shade good quality paint can be acceptable. Further details shall be discussed during design stage by the Engineer.
- (iv) Doors shall be vibration free and insulated against heat and sound transmission. Exterior and interior surfaces of the door leaves shall be finished to match the adjacent surfaces of car. The doors shall be free from dimples, warping, spot welding depressions and any other blemish.
- (v) When closed, door leaves shall be capable of withstanding loads imposed by passengers leaning on them under crush loading conditions. The doors shall be designed and tested such that the door leaves sustain such pressure with no permanent deformation. The Contractor shall submit test procedure based on best international practices.
- (vi) The door leaf design shall enable any portion of the door leaf or the car body visible to be cleaned.
- (vii) Each door leaf shall have a window.
- (viii) Overlapping of central seals of door leaves during door closed condition shall be minimum 10mm to 15mm. Both type of seals viz. End Seals and Central Seals shall be labyrinth type and not only adhesive type. Suitable profile of seals shall be ensured so that it shall not come out during service life.
- (ix) In respect of solar gain, thermal insulation, replacement criteria, strength, resistance to pressure, and the transmission of light, and solar heat gain, these windows shall be identical with those of the saloon windows.
- (x) Door windows shall be replaceable without removal of the door leaf.
- (xi) No single defect or failure of any part of any door system shall produce a situation capable of causing injury to any door user.
- (xii) Door guides and supports shall be mounted within the section of doorway protected by the door seals and other suitable means from inside and outside ensuring that no ingress of dust, debris, or any other foreign matter likely to result in excessive wear or incorrect operation of the door equipment. Proposed design shall be maintenance friendly and cleaning interval of the guide shall not be less than 1 year. At least four no. of special tools in each depot for cleaning of the guides shall be provided and cost of such tools is deemed to be included in quoted price of contract. The proposed design for sealing of the guides shall be got approved from the Engineer



- during design stage.
- (xiii) The materials used for the door movement and seals shall take into account of hygroscopic effects in high humidity tropical environments.
- (xiv) Sealing arrangements on external sliding door leaf shall meet the following requirements:
- The doors shall be sealed against draughts, water and noise. In the event of ingress of water or dirt with the doors in the open position provision shall be made to ensure that rapid draining takes place and that no surrounding equipment or systems are affected in any way.
  - Positive sealing along entire saloon door opening and door leaf inner surfaces to eliminate in-rush of tunnel air due to the piston effect.
  - Door sealing shall also be such that the saloon interior noise specification is satisfied.
  - Door sealing arrangement shall be adequate to prevent water ingress due to torrential rain and car washing through automatic wash plant.
  - The sealing arrangement shall take into consideration of car body manufacturing tolerance and deflections under fully loaded conditions.
  - All gaskets provided in the doors shall be so designed that there is no possibility of their getting loose during service. Life of the gaskets/seals shall be minimum 12 years.
  - The gap between the carbody exterior and interior leaves of the door panel shall not exceed 6mm (4+ 2, - 0) and packing used shall have service life of atleast 35 years.
  - Adequate care shall be taken to ensure no part of door machinery is visible from inside / outside the saloon.
- (xv) The Tenderer shall indicate the amount of time required to replace a door leaf on the car, adjust it, and test it.
- (xvi) A microprocessor based saloon Door Controller Unit (DCU) shall control each pair of saloon door and shall be an integral part of door control assembly. The door controller unit of a proven design shall be equipped with self-diagnostic functions and shall communicate with TCMS. Power supply to DCUs shall be in such a loop that the redundancy can be ensured in case of breakage of any one wire. The Contractor shall ensure that the system shall not be affected in single point failure. Details shall be submitted for review of Engineer.
- (xvii) DCU Hardware and Software support:
- It shall be possible for the Engineer to modify/change the parameters or closure/opening logic of door's circuit and implement the same as required by DMRC based on their operational and maintenance requirements. Full access to the software for the purpose above shall be provided.
  - Any hardware/software tool required for this purpose shall also be provided free of cost (2 sets for each depot).
  - The documentation including but not restricted to flow charts (for complete software), signal flows, and interpretation of signal etc. shall be provided.
  - Training shall be provided by the OEM experts to DMRC personnel to the complete satisfaction of the Engineer.
  - Single point uploading of software and downloading of faults/data on unit and train basis shall be ensured.
- (xviii) Design of doors and threshold plate shall ensure the specified requirement of maximum permissible platform gap as per Chapter 2 of Schedule of Dimension is satisfactorily met.
- The maximum permissible horizontal clearance between edge of the platform coping and edge of the carbody floor threshold plate with door open shall be 75 mm in underground corridor and 85 mm in elevated corridor.
- (xix) Specific measures shall be taken to maximise noise attenuation through doors. Door leaf shall be provided with honeycomb sheets or PU foam throughout. The doors assembly on the cars shall include carefully engineered sealing arrangement to reduce noise transmission into the cars. Details of thermal and noise insulation of doors shall be submitted for review by the Engineer.
- (xx) Limit switches used shall be of high reliability and with IP 65 protection. Life of the limit switches shall be at least 15 years. The Contactor shall furnish details during Pre-Final Design Stage.
- (xxi) The door position measurement and detection shall be accurate and real time measurement of



the distance moved by each leaf. Details shall be discussed and finalized during design stage. Also, Door closed position shall be double checked through two independent arrangements.

(xxii) Door System shall be at least SIL 2 compliant at train level for all the safety related functions including the following:

- Door opening when train not at standstill,
- Door opening at standstill on track side,
- Train departure with an open door,
- Non opening of two doors in case of emergency;

including but not limited software, hardware and control functionality etc.

The Contractor shall submit relevant certifications for the SIL levels as above. The SIL levels as above shall be validated and shall ensure that the train shall not move from a station unless the doors are closed and locked unless intentionally permitted by the Engineer. Details shall be worked out during design stage.

(xxiii) The operation of saloon doors shall be under train operator/attendant in the active driving console when the trains are driving in non-UTO mode. However, under UTO mode, the normal operation of saloon doors shall be under Signalling system.

#### 7.2.2 Door Mechanism

- (i) Doors shall be electrically operated from 110V DC supply through train line. The door operating mechanism shall be of a proven design in service.
- (ii) The door system shall continue to operate correctly with the car battery voltage supply range between 77V to 132V DC.
- (iii) The door operating mechanism shall be housed within the saloon above the doorway lintels. The design shall provide ease of access for maintenance. The complete mechanism shall be modular and mounted on a rigid frame so that it can be adjusted in situ for alignment and be removed as an integral unit from the car. The entire door mounting hardware and door actuation hardware must be readily accessible for adjustment and removal.
- (iv) All such fasteners, which can cause safety and/or adjustment, operational disturbances if loose during service, shall be provided with Nord lock arrangement. Contractor shall submit comprehensive proposal for Engineer's approval during design. Use of shims during installation or commissioning or adjustments shall not be acceptable, however if unavoidable use of shims shall be restricted to minimum which shall be discussed during design stage.

#### 7.2.3 Passenger Door Opening and Closing Times

- (i) Opening and closing time of the passenger doors shall be adjustable in the range of 2.0 to 4.5 seconds.
- (ii) The end of the closing and opening stroke (say 100mm) shall be damped or cushioned to reduce impact and/or minimise possible injury to passengers.
- (iii) All doors on the train shall fully open within 2.0 to 2.5 seconds from initiation of the open door command.
- (iv) All doors on the train shall fully close within 2.5 to 3.5 seconds from the initiation of the close door command.
- (v) The doors shall not lock and permit a door-closed indication if an obstruction is detected. The obstruction detection feature shall not permit the doors to lock either when a 15 mm wide by 100 mm long flat plate is held between the door panels or when a 19 mm diameter bar is held between the door panels. If an obstruction is detected, the door shall stop. The closing force of the obstructed door shall be removed. The door shall reopen by 50 mm (minimum 25 mm each door leaf) when an obstruction is detected. After a specified delay (adjustable between 0 and 5s), the door shall attempt to close again. If an obstruction persists, each door leaf shall stop again and the closing force of the obstructed door shall be removed. After the specified delay, the door shall attempt to close again. If the obstruction is still present the door shall reopen by 50 mm (minimum) 25 mm each door leaf) and remain stationary, reporting a fault to the TCMS.

The system shall have the provision of reclosing the door(s) without opening all doors in case of obstruction detection.



- (vi) Successfully closing of doors should be confirmed by mechanical locking. Interlocks should prove the closed and locked position of door system and then application of traction power should be enabled.
- (vii) The force required for closing/opening of any door leaf, when fully connected with the driving gear shall not exceed as mentioned in EN 14752:2015 or latest.
- (viii) The push back feature shall be operative after the door leaves have been closed and locked. It shall be possible to manually push back each closed door leaf to enable entrapped objects such as clothing and other articles, to be withdrawn, even after the mechanical lock has engaged. The force required to push back each door leaf shall not be less than 80N nor more than 120N. However final value shall be decided during design. Expected door gap to be created by push back during intentional operation should not exceed 15mm. (the final gap shall be decided during detail design stage of the door). Every operation of push back shall be recorded with time stamp and message shall pop up in cab HMI. The complete scheme shall be of proven type in worldwide metros.
- (ix) All the above settings shall be capable of being adjusted after experience in service has been gained. The initial settings shall be determined from an investigatory trial undertaken using the door mock-up, or the door test rig.

#### 7.2.4 Passenger Door Operational Criteria

##### 7.2.4.1 Reliability and Safety

The reliability and intrinsic safety of the doors of all high capacity metro trains are of paramount importance. One door failure often has the effect of disrupting the service, and usually by more than a two minute delay. It is of the utmost importance therefore that the door scheme shall be designed with all necessary safeguards against potential failure. The door operation shall remain reliable under all operating conditions from tare to crush loadings.

##### 7.2.4.2 Door Failure

- (i) Each saloon door shall be fitted with the means of isolating and locking both door leaves both from inside and outside. The isolation shall require the use of a key at a location normally accessible from the platform. The keyhole location shall be subject to review by the Engineer. It shall also be possible to isolate any closed and locked door from the driving console by the train operator using TCMS interface as well as remotely from OCC.
- (ii) When the isolation is activated, the door shall be mechanically locked in the closed position. Manually isolated doors shall be enunciated on the train operator's cab visual display unit (VDU).
- (iii) The door leaves will need to be provided with the appropriate means of applying a locking device. Full details of the Tenderer's proposal shall be provided.

##### 7.2.4.3 Interlocking

- (i) No spurious electrical signals shall cause any door to be released or opened. The Contractor will be required to provide a comprehensive Safety Audit to prove this point to the satisfaction of the Engineer.
- (ii) There shall be no single point failure of equipment or wiring, or two point failure with one failure undetected, which would cause a door to open without being commanded.
- (iii) The door controls shall be interlocked with the train's zero speed circuitry so that the doors cannot be opened until the train is stopped. However, loss of ATC power at zero speed shall not inhibit door operation. Zero speed signal shall be hard wired.
- (iv) Irrespective of the operating mode, the train shall not be able to move unless all the saloon doors are proved closed and locked. Separate Door closed and locking shall be proved for each door leaf. Separate close and locking switches shall be provided for each door leaf. The train line circuit performing this interlock shall be a failsafe, fully redundant circuit to provide maximum protection against erroneous door locked signal. A sealed cut out switch accessible to the train operator in each cab, shall be provided to bypass the interlock, to enable a train to be taken to the next station prior to being taken out of service, to attend to the defective door. Operation



shall be recorded by the Train Control Management System (TCMS).

In the event the train operator has operated the cut out switch to by-pass the door closed interlock, the system shall ensure that the doors are in closed condition before actuation of traction command.

- (v) At the centre of each door, (both exterior as well as interior) suitable dual colour LED indication lamp, duly approved by the Engineer shall be provided to indicate door status (including isolated state). The lamp shall flash yellow during opening/closing and shall glow yellow during open condition. The lamp shall glow red during isolated condition.
- (vi) All door control circuits for one side of car shall be separate and distinct from those for the other side of the car. There shall be no shared component unless specifically called herein.
- (vii) In ATP mode, it shall not be possible to energize the door open circuit if the train has not stopped in the correct location or if the car side adjacent to the platform has not been selected. However, the TO shall be able to open the doors by operating suitable switches in the event of the train not being inside the stopping window without involving the ATP cut-out mode.
- (viii) It shall be possible to operate any or both side doors in the maintenance depot or lines where ATP protection is not available. The details and schematic shall be provided for review of the Engineer.
- (ix) Both Door close and lock switches shall be hard wired.
- (x) All relevant door relays shall have paralleling of its contacts. Sealed type Mors-Smit relay (BK-400) shall only be used for door system. If any other proven relay is proposed, design details of the same shall be submitted for the Engineer's approval and may be provided only after Engineer's approval.

#### 7.2.4.4 Door Controls : Train operator's Controls

- (i) The doors shall be arranged for driving console control operation in non-UTO and from OCC in case of UTO. The control circuit shall be hardwired so that all the doors on either side may be operated automatically by either ATO command or manually.
- (ii) Door Control Push Buttons:  
Push button used in the door circuits shall have feature of flashing e.g. door open push button shall flash when door authorization is received and glow continuously when door is opened. The details and schematic shall be provided for review and approval of the Engineer during design stage.
- (iii) The opening and closing of doors shall only be possible from an operative driving console. The door controls shall be located on train operator's console and on respective door side, suitably located on side wall between the first door & front end. This control Push Buttons shall be suitably encapsulated during GoA4. The location shall be decided during mock up review.
- (iv) The driving console side control panels shall be located conveniently for operation of the doors on that side of the train. The control devices located on each side of the cab shall only operate the doors on that side of the consist.
- (v) All door control panels in the train operator's cab shall have an identical layout and shall be physically interchangeable.
- (vi) A switch shall be provided, preferably at the side of the driving console. In ATO mode, the automatic door open command may be overridden by operating this switch. Operation of this switch shall be monitored by TCMS.
- (vii) In case of unavailability/failure of door authorization signal from ATP system, adequate safeguards shall be provided and also incorporated in control circuit to eliminate the probability of error of opening of doors on wrong side (other than platform side) during revenue service. Manual opening/closing of the doors from the cab shall be possible by simultaneous operation



of Two Push Buttons on door control panel on respective side using both hands.

#### 7.2.5 Interfaces

##### 7.2.5.1 With TCMS

The door controller unit shall have communication link with TCMS. TCMS shall also be interfaced with the related circuits and interlocks so that all the door related status and commands are logged.

##### 7.2.5.2 With ATP/ATO

See Appendix 'TD' for full details of the division of responsibility between the Contractor and Signalling Contractors.

##### 7.2.5.3 With On-board Public Address System

The door control shall be suitably interfaced with On board Public Address System to achieve the following:

- (i) A chime with car based control shall sound over the PA system as the doors are opening, as a signal to the visually impaired. The chime shall stop when the doors are fully open.
- (ii) A door close announcement followed by a chime controlled preferably by the DCU (scheme to be finalized during design stage) shall be triggered each time the "Door Close Command" is initiated. The door close chime shall continue to play till the Doors achieve locked position. The chime shall also play in case an obstruction is detected. The chime shall warn the passengers inside the train as well as those on the platform about the door operation using identical chime sound for both internal and external speaker. It shall be possible for depot to adjust the volume of speakers easily as per the need. Selection of the type and adjustment of volume of the chime shall be independent from announcements. It shall also be possible to separately adjust the volume of the internal and external chimes.
- (iii) While chime is played over the PA system, any existing auto announcement shall be aborted.

#### 7.2.6 Emergency Release of Doors

Three means of operating doors by staff shall however be provided for emergency situations as described below:

- (a) On each side of every car, a device (Emergency Access Device - EAD) shall be provided. The location of EAD shall be finalized through interface with the PSD Contractor during design stage with the approval of Engineer. This device shall be operable from outside the vehicle from platform level or track-side. Operation of this device shall release the "locking" mechanism on the adjacent door. Manual emergency release device shall be unobtrusive, flushed with, or recessed into, the car side, but readily available in an emergency. The manual emergency release device shall be provided with spring loaded cover to ensure water tightness. This shall require a special key so that only authorised personnel can operate the same.
- (b) A second device (one for each side) shall be provided inside the driving console. This device shall be operable from inside the driving console. Operation of this device shall release the "locking" mechanism on adjacent passenger saloon door of the DM car. This device shall be unobtrusive, flushed with, or recessed into the side wall / interior panel.

Any operation of the above mentioned manual door release devices shall be indicated to the train operator on TCMS/to OCC along with the position of the door(s) as open or close.

- (c) Third device shall be provided inside each saloon door coving. Operation of this device shall release the locking mechanism of the respective door. The device shall be accessible only to authorized DMRC personnel.
- 7.2.7 During detail design stage, all events that shall trigger recording of data in the DCU shall be finalized. Various parameters, that shall be available for display shall be selectable. For each event, the complete data for minimum previous 300 secs shall be recorded & retrievable. The data shall include each input output & status of different parameters. Adequate memory shall be available for recording of at least 100 records. Complete diagnostic tools (software/hardware) shall be provided.

Provision shall also exist to monitor all inputs/output ON LINE on a maintenance device. Unless the data is viewable on a laptop loaded with maintenance software (to be supplied by contractor for each depot) the contractor shall provide two sets of maintenance devices and diagnostic tools for each involved depot.

7.2.8 Accessibility of EAD with provision of PSD shall be properly interfaced with designated Contractor.

### 7.3 Front End Emergency Door/ Detrainment Door

7.3.1 Arrangement for emergency egress of passengers from the front shall be provided on the cab front. The door arrangement shall be aesthetically designed ensuring seamless clear view of the track from driving car. The door shall aesthetically harmonize with the lookout glass and driving car front and shall not block the front view giving a look of single front glass. The glass of Front End Emergency Door shall meet the specifications of the windscreen Glass (ERTS 4.13.2). The visibility of the joint between the front door and look out glass shall be bare minimum. The detrainment door system shall be SIL2 compliant and shall be provided with a sealed cover door actuating mechanism. The clear width of the door way and ramp when operated shall not be less than 1100mm with a headroom not less than 1900mm so that two files of passengers can be simultaneously detrained without supervision.

7.3.2 During design stage, Contractor shall provide all details to the Engineer of the metros where such options can be seen and overall design is decided. If required, the contractor shall facilitate visit of Employers representatives to such metros. Suitable arrangement for ensuring safe detrainment of passengers from saloon to the track plinth (both elevated and underground sections) shall be provided. The folding ramp shall be simple in operation and should be operable by passengers without assistance during emergency. The ramp shall have full length longitudinal handrail and fluorescent material marking on both sides. The detrainment door ramp shall be designed for load of 500 kg/m<sup>2</sup> or more and it shall not sag during evacuation process. The ramp angle shall not be more than 16.5 degree. The ramp shall also be suitably supported on the track to ensure no tilting of the ramp on straight as well as on curved sections. Retrieval of the ramp shall be easy. Contractor shall demonstrate safe use of the emergency door and ramp in the elevated and tunnel section on different radius curves specified in the specifications. The door design shall be consistent with the latest applicable fire safety standards. Further details shall be decided during design.

7.3.3 The door shall be vibration free and sealed against water ingress and sound transmission. It shall be provided with a safe, simple and secure locking mechanism which shall throughout be unaffected by single point failure.

7.3.4 The opening of the detrainment door & ramp shall be possible by one person. The retrieval and stowage of ramp should be easily accomplished by a single trained staff without dismantling any equipment. Any tool, if required, for manual operation by single person shall be provided in the driving console area. In addition to manual arrangement operable by one person, suitable portable power operated devices for stowage of door and ramp shall also be provided in each train at suitable location. If battery of Portable power is weak, stowage of door shall be operated manually. All necessary ancillary equipment to enable the train to be moved after emergency detrainment shall be provided as parts of the scope of equipment under this clause.

7.3.5 For operation of the door, simplicity of operation is imperative. Multilingual (regional language(s) and English and/or Hindi) Instructions shall be displayed to enable passengers, unfamiliar with the equipment to operate the emergency door, in either mode, when the train operator is incapacitated.

7.3.6 There shall be two operation modes, emergency operation mode and depot/maintenance mode. While in emergency operation mode complete deployment shall not take more than 1 minute. Deployment and stowage timings shall be reviewed by the Engineer.

7.3.7 The door status shall be interlocked with the train control circuit so that once the door is found unlocked and open:

- (i) Driving console light, Head lights and Flasher lights are automatically lit and CCTV camera automatically operated.
- (ii) Emergency brakes are applied on the train.
- (iii) Such event is logged in TCMS.



- (iv) The detrainment process shall be monitored with CCTV camera. One camera dedicated for detrainment process shall be provided. Flasher light shall automatically turn ON when detrainment door is open. Actuation of door actuating mechanism shall be suitably interlocked and immediately relayed to OCC to take further actions like PA broadcast, switching on onboard CCTV to high speed, floodlit the detrainment area (flood light to be provided separately) and beyond to allow OCC to review the detrainment from the train. The Contractor shall submit detailed Proposals of the operation of the detrainment doors for review and acceptance by the Engineer.
- 7.3.8 The door shall be suitable for multiple operations. There shall be no sagging / out of shape of the door at the end of such test.
- 7.3.9 Contractor shall furnish detail evacuation plan. The Evacuation Scenario will also cover the following conditions:
- Evacuation in Emergency, e.g. Fire, collision. The proposed car arrangements shall be compliant with the evacuation requirements specified in Railway Group Standard GM/RT2130 'Vehicle Fire, Safety and Evacuation' or better.
  - Controlled evacuation e.g. failed train or failed power supply. It will include study of evacuation time, the battery capacity calculation and other relevant documentation duly considering the infrastructure as available.

The contractor shall note that during acute emergency, side evacuation may become inevitable. The Contractor, based on the experience, shall advise the quickest way for evacuation in emergencies and shall make suitable provisions in design after final agreement with the Engineer. For side evacuation, suitable arrangement for filling up of the gap to walkway may have to be provided in each car. Details shall be decided during design.

#### 7.4 Cab Side Doors

Cab Side Doors need not be provided. Suitable arrangement for train operator to board the train in depot (non-platform area) shall be provided on first door(s) of DM car. Detailed arrangement to be finalized during design stage.

#### 7.5 Saloon-to-Cab Door

- 7.5.1 Suitable designed temporary door in the removable, temporary partition between the saloon and the driving console area to permit access to the passenger saloon shall be provided. The clear door opening shall be approximately 1100mm wide. In normal operation, opening the door from the saloon shall require the use of a special key.
- 7.5.2 The door shall not get jammed due to pressure exerted by passengers or distorted due to minor mishaps.
- 7.5.3 The finish of the door shall harmonize with that of the cab and the passenger saloon.
- 7.5.4 Opening the door from the cab shall not require any key.
- 7.5.5 The locking mechanism shall only use heavy duty locks, levers and actuating arms with proven record in metro applications.
- 7.5.6 The door shall not be possible to be bolted, wedged or otherwise locked, from either side of the door to prevent opening.
- 7.5.7 In emergency, it shall be possible for a passenger to gain access to a lever to actuate the locking device, to permit access to the driving console area, for operation of the emergency end door. The lever shall be protected by a suitable transparent breakable cover which shall be designed to allow for easy but deliberate breakage. The material when broken shall not leave any sharp or jagged edges.
- 7.5.8 A visual and audible alarm shall be activated in the event that the saloon-to-cab door in the unoccupied cab is opened.

#### 7.6 Door Leaf Construction

- 7.6.1 All exterior doors shall be of stainless steel of same finish as sidewall and should have the same durability as the vehicle body. The interior of door leaves shall be stainless steel/ Aluminum with matching shade good quality paint/powder coated and compliant with the visual design and withstand severe wear and tear. It shall not be possible for a door to become detached from the vehicle under any operating conditions, including heavy side load from standing passengers or sudden pressure transients.

- 7.6.2 The construction of the door shall be such that it is able to resist without deformation or damage a load equivalent to that which could occur on a crush loaded train. The door shall be as light and rigid as possible.
- 7.6.3 The door leaf edges shall be such that when the doors are closed they form a weather tight seal extending the full height of the door.
- 7.6.4 Any seal shall not require regular cleaning. Seals and sensitive edges (if used) shall be effective under all operating conditions from tare to crush loading and particularly shall be resistant to atmospheric and chemical deterioration and to vandalism.
- 7.6.5 It shall be ensured that water does not enter/get trapped inside the door panels due to condensation or otherwise. The adhesives, if used, shall be type tested and certified for their performance under temperature cycles with 90% humidity & condensate.

#### 7.7 Platform Screen Door (PSD):

It is intended to provide Platform Screen Doors (PSD) at all stations of line 2 & 7. These doors shall not be of full height and shall have provision to allow free flow of air for platform ventilation.

The train shall be fully compatible for PSDs functionality and shall be complete with any equipment/software (as per appendix TD), if required to be provided on rolling stock except for those which are necessarily required from PSD contractor. Any other issue shall be resolved during interface coordination meeting with the respective contractor(s) for trouble free commissioning and operation of the PSD(s).

#### 7.8 Passageway Sliding Door for 'First Class' Car:

A suitably designed Passageway Sliding Door for 'First Class' Car shall be provided at one end of the 'First Class' Car to distinct it from other cars of the train. The clear door opening shall be approximately 1100mm wide.

The appearance, material and finish of the surface of the sliding door shall be same as the passenger saloon doors. The upper part of the sliding door shall be glazed with a single pane tinted safety glass.

It shall always be possible to open this sliding door from either side of the door. Under no condition this door shall be locked from either side of the door. However, suitable provision shall be made to lock this sliding door in fully open condition to ensure smooth passage of passengers in case of emergency condition. Details of design shall be discussed during design stage.

#### 7.9 Deliverables

- 7.9.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	7.2.1 (xii)	Special tools for cleaning of the door guides.	At least four no. of special tools in each depot.
2.	7.2.1 (xvii)	DCU hardware/software operation & maintenance tool.	Two sets for each depot.
3.	7.2.7	Complete sets of maintenance devices and diagnostic tools (software/hardware) as per clause 7.2.7	Two sets for each depot.

#### Note:

- The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
- The cost of these deliverables is deemed to be included in the quoted price of contract.



## 8. HV AND PROPULSION EQUIPMENT

### 8.1 High Voltage and Propulsion Configuration

- 8.1.1 The High Voltage and Propulsion System shall be suitable for operation at 25kV AC single phase for the frequency variation from 48 to 52 Hz. The high voltage and propulsion system shall be configured such that it performs equally reliably for all consists, for all normal and abnormal duties defined herein.
- 8.1.2 All live parts on the roof including Bus bars, Joints, Terminals etc. shall be suitably insulated for 25kV AC Arrangements for insulation shall be finalized after approval from Engineer.
- 8.1.3 The Straight line distance from any live part on the roof, roof edge and platform shall be more than 3.5 meters and the clearances shall be in accordance with EN 50122-1.
- 8.1.4 All propulsion equipment shall be rated to ensure for operation of normally operating train for a further period of 2 hours or a round trip whichever is more with single unit in operation.
- 8.1.5 Complete map of spectrum of harmonics generated by the unit/train in traction and regeneration mode shall be submitted during design. The same shall be verified during system test and validated during line test. Harmonics emitted by the train and complete fleet operating in the system, including feed extended zone shall be compatible with the voltage distortion limits specified in IEC 61000-3-6 & IEEE 519-1992, 2014 and shall be validated as type test. All traction units shall be suitably interlaced to minimize the effect of harmonics in the power system. The overall harmonic voltage distortion levels viewed at pantograph shall not exceed 2% of the fundamental component under all modes of operation including regeneration with multiple number of trains in operation.
- 8.1.6 Contractor shall submit complete roof layout along with the clearance between roof equipment. This shall also include water drainage arrangement and insulation of exposed charged items.
- 8.1.7 It shall be possible to operate standalone single unit of 3 cars within depot.
- 8.1.8 Separate push button shall be provided on driver's desk to open line circuit breaker(s) in the event of extreme emergency by Train Operator.
- 8.1.9 It shall be possible to operate already working train for 2 hours or round trip, whichever is more, with one unit isolated in high tractive effort mode without exceeding the specified temperature limits.
- 8.1.10 Only one cut-out mode, low speed cut-out mode (25 kmph) shall be provided.
- 8.1.11 In the event of momentary jump in the line voltage due to unforeseen reasons, the line circuit breaker shall remain closed up to line voltage of 35kV for 2 second.
- 8.1.12 The stipulations of EN 50388 and IEC 62313 shall be complied. Further, the control system shall ensure that the train as an electrical system shall always behave as an inductive load with power factor near to unity (not leading) under all operating conditions of powering mode, braking mode and coasting mode at all loads. The Contractor shall include validation of same as a part of combined test bed and on mainline test.
- 8.1.12.1 Two trains on each line shall be instrumented with separate Power Quality measuring instruments, data acquisition systems and power analyser (with provision for permanent installation and necessary software/analysis tool) to measure, record and analyse the power quality. The measurement with these instruments shall include but not limited to Time, kW, kVAR, kVA, THD, TDD, Total pf and Displacement pf. The instruments supplied shall have the adequate capability of measuring and data acquisition to analyse higher order harmonics (up to 50<sup>th</sup>) and measure power quality parameters mentioned above with minimum accuracy of 0.1% and sampling rate of 100 kHz. Details of instruments shall be finalized during design stage.
- 8.1.12.2 Other trains shall also have necessary provisions (suitable space, wiring etc.) for installation and recording power quality parameters as per para 8.1.12.1 above.
- 8.1.12.3 If Contractor proposes to measure the power quality parameters as mentioned in para 8.1.12.1 above, through TCMS. In such case, TCMS shall have the adequate capability of measuring and data acquisition to analyse higher order harmonics (up to 50<sup>th</sup>) and measure power quality parameters mentioned above with minimum accuracy of 0.1% and sampling rate of 100 kHz. Also, a suitable power analyser, software/analysis tool shall be built in. However, this proposal shall be subjected to approval of the Engineer.
- 8.1.13 Design shall be suitable for 90 second headway.

- 8.1.14 The staggered closing of VCBs of trains shall be suitably ensured under both normal and extended feeding scenarios arising after power supply restoration to avoid tripping of VCB of substation due to high inrush current. Necessary command required for closing of VCB(s) from OCC shall be ensured as a part of interface design. Design shall be suitable for 90 sec headway.
- 8.1.15 Staggered acceleration of the trains within the same power supply feeding zone shall be suitably ensured under UTO operation for both normal and extended feeding scenarios arising due to power supply disruption or bunching of trains within the same feeding zone as a part of interface design for avoiding tripping of VCB of substation. Design shall be suitable for 90 sec headway.
- 8.1.16 In case of addition of one (T+M) unit (if required) the ratings of Propulsion equipment like Main Transformer, CI etc. shall be same as that of existing 6 car train.

## 8.2 HV Power Collection

- 8.2.1 Power shall be drawn from the OCS by pantographs.
- 8.2.2 The pantograph for the 25kV AC system shall be suitable for flexible auto-tensioned OCS consisting of catenary and contact wire as well as rigid catenary system provided in the tunnel section and shall be equipped with Auto-Dropping Device (ADD).
- 8.2.3 The pantograph shall be capable of sustained operation and satisfactory current collection from 150mm above the lockdown pantograph level up to the full range of contact wire height, and at all operating speeds as specified. The locked down height of the pantograph shall be limited to 4048 mm from the rail level.
- 8.2.4 A pantograph auto-drop function, which shall drop the pantograph automatically when excessive height is detected, shall be provided. An indication shall be provided to the Train Operator when this function has operated.
- 8.2.5 Pantograph controls shall be configured in the cab such that any one pantograph or all pantographs can be raised or lowered. Control of pantographs shall be available through hardwire and from TCMS.
- 8.2.6 Panto horns as well as panto strips shall be secured with Nord lock or equivalent suitable arrangement. The carbon strip shall be single piece carbon strip tested against EN 50405, glued with Epoxy phenol resin and arrangement for prevention of water ingress in support beam of carbon strip. V-type base support shall be provided as to ensure that strip remains fixed even if gluing ages.
- 8.2.7 The pan-head shall be designed with pure carbon strips with a view to achieve minimum dynamic mass. The Contractor shall furnish the expected frequency for replacement of strip in terms of kilometres earned by the car.
- 8.2.8 The width and profile of the pantograph shall be such that the Kinematic Envelope of the car is within specified limit in accordance with Appendix TE. Same panto shall be suitable for all sections i.e., tunnel, viaduct & ground. The contact wire, under the worst conditions of the sway on the Car and stagger shall be within the carbon strip portion of the pantograph. The Contractor to submit supporting calculations and wind tunnel test results during design review. The electrical clearance between the live portion of the pantograph and the roof shall not be less than 290mm. The minimum mechanical clearance from fixed structures at any time should not be less than 100mm. The straight line distance from panto horn live edge, roof and platform shall be more than 3.5 meters.
- 8.2.9 The pantograph shall be a single arm, direct air operated type with two strip pan-head arrangement and compliant to IEC 60494-2. The pantograph shall be of a proven design for both flexible and rigid catenary system. In case, the pantograph has not been used on both types of catenary, the supplier shall establish the suitability of the offered design on theoretical basis, which shall be validated by service trials. The pantograph shall be complete with air control equipment including air filter and pressure regulator. In case air is supplied to pantograph via an air-feed insulator. The creepage length of the insulators shall not be less than 900mm and shall be suitable for PD4 category and for unfavourable operating conditions of pollution (Ref EN50124).
- 8.2.10 Pneumatic pipe, other fittings and equipment provided on the pantograph frame shall be insulated from the frame to avoid any damage to pipes due to flow of fault current on account of earthing of the frame from any stray wire accidentally thrown by birds etc. on the roof. The insulation shall be suitable for 25kV AC system.
- 8.2.11 Incidences of stray wire being accidentally thrown by birds etc are quite frequent. With a view to



provide definite design solution, the Contractor shall examine various possible solutions and implement the chosen one on the trains, with due consultations with the Engineer. Base frame and roof bus bars/ equipment charged at 25 kV and exposed shall be suitably insulated for 25KV to ensure that direct earth fault does not occur between the base frame and car roof. Arrangement for insulation shall be got approved from the Engineer.

- 8.2.12 One set of on board Set up for monitoring, recording & analysing pantograph current collection performance shall be provided for each Depot. The cost of these setup shall be deemed to be included in the quoted price of the contract. Necessary training shall be provided to the Engineer.
- 8.2.13 The pneumatic connection for roof to the pantograph shall be through insulated air pipe suitable for the OHE voltages specified.
- 8.2.14 In case of entanglement of any pantograph with OHE, other pantographs of the same train shall be protected by Auto Dropping Device (ADD) feature in train. The system shall react immediately to lock down the other pantographs to avoid any physical damage to the system. It shall be demonstrated through the tests.
- 8.2.15 Deleted.
- 8.2.16 Contractor shall provide component manifold type control panel for pantograph.
- 8.2.17 Contractor shall provide at least one wayside measurement device in each depot for measurement of carbon strip width of pantograph and complete roof body inspection for any external agents (if any) during entry /exit point in the depot and details of equipment shall be finalized during design stage. The cost of these devices shall be deemed to be included in the quoted price of the contract.

### 8.3 25 kV Vacuum Circuit Breaker and Earthing Switch

- 8.3.1 A roof-mounted vacuum circuit breaker (VCB) of proven design shall be provided for the 25kV AC system vehicles, located close to the pantograph. The VCB shall be of the single bottle type having a short circuit rating of 400MVA, and conforming to IEC 60056, in conjunction with C3 category, type tested with 300,000 operations & IEC 60077-4. Protection class for the external portion and internal portion shall be IP 67 and IP 20 respectively. The creepage distance of the insulator shall not be less than 900mm for the highly polluted environment in accordance with IEC 815. The auxiliary contacts and control equipment shall be located beneath the base plate so as to be accessible from within the vehicle. The control cable shall be compliant to the requirements of EN 45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions as a minimum or better international standards applicable to similar type of Metro operation in respect of fire, smoke, & toxicity characteristics. A 110 V DC connector of proven design shall be provided. The VCB base plate along with bottom cover shall be suitably protected to prevent corrosion in adverse environment of Mumbai the mounting plate of VCB shall be provided with a proper sealing to avoid ingress of water from roof. The past three year's record of proposed VCB shall establish NIL failure of vacuum tube and not more than two component failures in last three years. The VCB shall be suitable for repeated switching within short time comparable with the short (6m) neutral sections. Type test reports shall be submitted. Adequate Spare auxiliary interlocks duly cabled up to terminal block in the electrical cubicle shall be provided.
- 8.3.2 An Earthing Switch shall be provided, operable from inside the car, enabling each high voltage (HV) circuit to be earthed during maintenance. This switch shall be interlocked with the pantograph to prevent the pantograph being raised while the HV circuit is earthed and to prevent the HV circuit from being earthed while the pantograph is raised.
- 8.3.3 The Earthing Switch shall also be provided with a sturdy key lock proven for EMU metro applications. The key can only be removed after the Earthing Switch is in earth position and pantograph air supply is isolated. The Earthing Switch shall be hand operated from inside the vehicle. The exposed portion of switch shall be painted similar to VCB. This key shall be used to release multiple keys to open / close the covers of boxes of propulsion equipment for maintenance in accordance with the existing procedure. The Contractor shall submit for review and approval of the Engineer if any other alternative procedure is proposed, with due justifications.
- 8.3.4 Circuit breaker operation shall be recorded with time stamp and train location.
- 8.3.5 Design life of all the auxiliary switches of VCB shall be minimum 15 years. In case the Contractor propose the design life less than 15 years or the life obtained due to failures is less than 15 years, the Contractor shall supply/handover the quantities required for replacement before 15 years as free of cost to DMRC.

**8.4 Lightning Arrestor**

8.4.1 Gapless type lightning arrestors of proven design in accordance with specification IEC 60099-4 shall be provided on the roof. One LA shall be provided on incoming side after the pantograph and another LA shall be provided before the HT Transformer Bushing after the VCB, for protection against line voltage transients caused by lightning or system switching. The LA shall be rated for not less than 42kV with compatible rupture capacity. The failure of arrestor shall not be explosive in any case. No splintering etc. shall be permissible. This shall be included in the type test plan. The arrestor shall be exposed to line harmonics and line voltage/frequency fluctuations. Contractor is advised to take actual measurements before design. Frequency fluctuation of the order 47Hz to 54Hz may be considered as datum.

**8.5 25 kV Potential Transformer (Explosion proof)**

8.5.1 A 25 kV Explosion Proof Potential Transformer, duly type tested, to be mounted, on the roof, meeting the requirements of IEC 60044-2, for protection / measurement shall be supplied. Adequate protection shall be ensured to avoid secondary short circuit at PT output and effect of harmonics on the performance.

8.5.2 Deleted.

8.5.3 Accuracy class for measurement as per IEC 60044-2 shall be 0.5 or better.

**8.6 AC Current Transformer**

8.6.1 An AC Current Transformer, to be mounted along with 25 kV cable for protection and measurement, meeting the requirements of IEC-60044-1, shall be supplied.

8.6.2 Deleted.

8.6.3 Accuracy class for measurement as per IEC 60044-1 shall be 1 or better.

**8.7 Main Transformer**

8.7.1 The main transformer shall have a service life of at least 40 years, demonstrable through design calculations to the satisfaction of the Engineer.

8.7.2 The transformer shall be designed to conform to IEC 60310 and the temperature rise limits of windings and oil shall correspond to IEC 60310 limits minus 20°C.

8.7.3 The transformer shall be modular in construction, complete with oil pump, oil pump motor, radiator with blower, conservator and protection equipment all assembled as a single module. The Tank and conservator design shall be such that there is no possibility of any trapped air bubble in the tank.

8.7.4 The transformer shall be ester oil immersed to ensure the minimum acceptable standard for fire load. Force air cooling may be adopted, if required. The fire load of the transformer shall be furnished and ensure compliance with the specified fire load vide ERTS 2.19.3

8.7.5 The transformer shall be under-slung and the resilient mounting arrangement shall be described in detail by the Tenderer.

8.7.6 Measures shall be included to monitor for, and protect against, main transformer failure and leakage. The design shall minimize the fire load of the transformer.

8.7.7 The kVA rating of the transformer shall be designed to deliver the power to the continuous load as calculated with specified run cycle at ERTS 8.10.5. The overloading of transformer for typical run shall be specified and type tested. Short time Ratings (say 15 sec & 110 sec as the case may be) shall be submitted along with the justification.

8.7.8 Following protecting devices shall be necessarily provided:

- I. Thermometers with thermo-sensitive device to activate alarm contact, when oil temperature exceeds a pre-set value and trip command for temperature exceeding the max set value.
- II. Oil flow relay to detect stopping of oil flow due to pump failure to trip the VCB.
- III. Pressure relief valve to discharge abnormal pressure generated by gassing of oil with tripping of VCB and locking of transformer.
- IV. Oil level gauge to monitor the oil level. Prismatic glass shall be used for oil level gauge. The gauge shall be mounted such that it can be easily seen from the side of the car. Alarm and trip command



- based on oil level, detected with Oil Level Detectors (OLD) shall be provided. Redundancy of OLD shall be provided if applicable.
- V. All sensors shall be so located that they are easily accessible for maintenance /replacements.
- VI. All oil level sensors and relays shall be duplicated if applicable.
- VII. Transformer bushings shall be provided with heat-detectors/LHD unit as per ERTS clause 2.20.
- VIII. Heat detectors/LHD on low voltage/high voltage terminal boxes linked to TCMS/fire detection & control unit (refer ERTS clause 2.20) so that their status is monitored.  
The above information shall also be logged in TCMS.
- 8.7.9 IP level of blower motor, pump motor and complete transformer including terminal box shall be IP65. Contractor shall declare the Vendors for Transformer's sub assemblies and shall submit an undertaking & commitment from Vendors to deal directly with Engineer in case of future procurement.
- 8.7.10 The provision shall be made to switch off and on the radiator blower fan with respect to temperature rise of the transformer.
- 8.7.11 All motors shall be dynamically balanced and shall have resilient four point mounting arrangement.
- 8.7.12 All gauges and sensors shall have easy access for monitoring and replacement.
- 8.7.13 Radiator filters shall be easily replaceable. Condition of the filters should be monitorable. Cleaning frequency of radiator filters shall not be less than a year.
- 8.7.14 Gaskets and sealants used shall be suitable and compatible for use with the transformer oil and high temperature. Test report and design life of gasket and sealants to be submitted.
- 8.7.15 Suitable oil filling equipment, complete with centrifuging, oil testing and other accessories shall be provided in each depot and cost of these accessories is deemed to be included in quoted cost.
- 8.7.16 Transformer cooling arrangement shall be designed to ensure completion of round trip (without loss of time) of already working train with only one radiator fan working.
- 8.7.17 In case of already working train, the non-working of radiator fans/ oil pump for at least 1 minute shall not affect transformer functionality and train performance in any way.
- 8.7.18 Maximum Transformer efficiency shall be achieved at AW2 load and Normal Mode as per IEC60310 and shall not be less than 97% at 22.5kV. The transformer efficiency shall also be validated in system test bed and line tests.

### 8.8 25kV Cable with HV Bushing and T-connector

- 8.8.1 Copper cable of adequate voltage rating and diameter shall connect the vacuum circuit breaker to the main transformer. The cable shall be laid in a stainless steel pipe. The cable insulation and sheathing shall be halogen free, flame retardant, and having low smoke emission in compliance with EN 45545 Part 1 to 7 (Category 4-A, Hazard level HL3) latest editions as a minimum or better international standards applicable to similar type of Metro operation. The details for roof end and the transformer end terminations shall be provided for the Engineer's review. The cable shall not have any straight through joint/ connector between HT bushing on the roof and transformer bushing in the transformer.

### 8.9 Power Converter – Inverter

- 8.9.1 There shall be Two Converter and One Inverter in each motor Car feeding all the traction motors. However separate CI for each Bogie will also be acceptable. The power converter - inverter shall be a proven for metro application, four quadrant IGBT based unit, with VVVF control. The equipment shall conform to IEC 61287-1. Natural or forced air/water cooling shall be adopted. However, if forced air/water cooling is offered complete details of the arrangement including the method of dust filtration shall be furnished.

During design of cooling system, it shall be noted that Mumbai's ambient conditions are heavily dusty with abrasive dust, high humidity and environment pollutants. The cooling system, natural/forced air shall ensure that the devices/components/electronics is completely sealed against intrusion of dust/water. IP65 level of protection shall be ensured. The sealing arrangement shall be such that this protection level is ensured after normal maintenance and replacements of components. Gasket shall have minimum life of 12 years.

- 8.9.2 The system shall be designed to minimize switching losses, switching noise, and weight, and improve heat dissipation.
- 8.9.3 The current rating of the semiconductor shall be such that the junction temperature has the minimum thermal margin of 10°C in the worst loading conditions taking into account the extreme ambient conditions in Mumbai and surrounding. Contractor shall consider the temperature rise of the air in vicinity of the equipment on account of different factors including proximity impact in the underframe, difference in wheel diameter of the bogie(s) and rescue operation etc.
- 8.9.4 The converter/inverter (CI) system and transformer shall be capable of withstanding the maximum short circuit under fault conditions. Short circuit protection of IGBTs shall be implemented.
- 8.9.5 The continuous rating (not thermal rating) of the converter shall be based on the continuous rating of the traction motor and inverters after accounting for the efficiency and power factor of the traction motor.
- 8.9.6 The converters in a train shall be controlled such that the harmonic currents in the track in the CBTC/ATP frequency range shall be below the specified level by Signalling Contractor under the worst conditions. The Contractor shall interface with signalling and train control contractors for limiting values of the return current in track in CBTC/ATP frequency range. The frequency details shall be as specified by the Signalling contractor (Appendix TD).
- 8.9.7 The power converter - inverter shall be designed to cater the pantograph-bouncing phenomenon. Adequate compensation using suitable rating of DC link Capacitor shall be provided for the pantograph bounce time or short time line interruption cases. Contractor shall submit the design calculations.
- 8.9.8 The box for the power converter - inverter shall be of stainless steel/Anodized Aluminium so as to avoid any corrosion in service on any account and the box shall last for the lifetime of the converter / inverter unit without needing any attention. The IP protection level of Converter box and that of aux. converter shall not be less than IP65. The connectors shall have IP67 protection. The cooling arrangement shall ensure no dust deposition on the component and associated electronics. The box cover which may have to be removed for maintenance shall be suitable secured against falling. Hinged opening cover arrangement shall be preferred.
- 8.9.9 Following special modes of operation shall be provided using VDU interface of TCMS:
- I. Low speed control to operate the train during train washing.
  - II. Low speed & low acceleration (settable parameters) during shunting operations
  - III. High Tractive Effort mode which may be used during MC isolation or rescue operation.
- 8.9.10 Slip/slide control during powering and electrical braking may be provided using speed sensor less vector control subject to its provenness in Mass Transits. Uncontrolled slip/slide should be clearly recorded in TCMS as critical fault.
- In case of excessive slip of wheels during acceleration, suitable speed regulation/restriction of 40 kmph shall be imposed up to the next station and it shall also pop-up as a fault in TCMS.
- 8.9.11 The Contractor shall submit quality specification of the regenerated energy including its harmonic analysis. The same shall be commensurate with the latest trends in metro transit systems and shall be in compliance with an accepted international standard as per ERTS 8.1.5. Interlacing of traction units within the train and the fleet shall be implemented to minimize the overall effect on the power system. Contractor shall submit detail document on the interlacing strategy and harmonic reduction measures during design stage.
- 8.9.12 Protection and diagnostics:
- I. Control circuit logic shall permit testing/monitoring, operation and fault simulation of the power converter-inverter. Appropriate test equipment shall be supplied.
  - II. The power converter-inverter shall carry out self-tests to ensure the integrity of the equipment. Sufficiently detailed status, fault and diagnostic information shall be transmitted to TCMS, to enable protective or corrective action to be taken immediately, when necessary.
  - III. The power converter-inverter shall use a control scheme that contains extensive self-diagnostic logic, which shall be fully integrated with TCMS. At a minimum, the diagnostics system shall identify a range of credible faults, identify whether a Least Replaceable Unit (LRU) is responsible for the fault, and whether the LRUs (or non-LRUs) must be replaced or the system merely reset. The diagnostics system memory shall be retained when the train is powered down.
  - IV. The train operator from the cab shall be able to isolate any power converter / inverter.



- V. Current drawn by each motor shall be measured and recorded.
- VI. Redundant Temperature/Heat sensor/LHD location shall be in proximity of IGBTs and shall be linked to TCMS/Fire Detection & Control Unit (refer ERTS clause 2.20) so that their status is monitored.
- VII. The auxiliary contacts of the contactors used in the converter-inverter and aux/. Converter shall be paralleled and shall be 100% redundant.
- VIII. Protection scheme for propulsion system shall include but not limited to:
- 1) Primary Circuit
    - Over Current of Primary Circuit
    - Interphase short in secondary circuit
    - Interruption of catenary circuit
  - 2) Main Transformer
    - Oil Flow Stop
    - Over Temperature of Main Transformer
    - Pressure Relief Valve
  - 3) Converter/Inverter
    - Over Voltage of Primary Circuit
    - Low Voltage of Primary Circuit
    - Frequency Irregular
    - Waveform Irregular
    - Over Temperature of Power Unit
    - Over current of Secondary Circuit
    - Ground Fault
    - Low Voltage of DC Circuit
    - Over Voltage of DC Circuit
    - OVT Failure
    - Wheel Slip / slide
    - Tractive Effort Failure
    - Regenerative Effort Failure
    - PWM Failure
    - Rotation Backward Detection
    - CPU Fault
    - Low Voltage of Control Power Source
    - Low Voltage of Gate Power Source
    - Low Voltage of DC 110 V Power Source
    - Calculated Speed Fault
    - Over current of Main Motor
    - Phase unbalance of motor current
    - Over Temperature of Main Motor
    - Traction Motor Current Unbalance in 4 motors
    - Fan Fault
    - Fault of Charging Circuit

The settings and calculations of above mentioned protections shall be discussed during Pre – Final Design Stage.

8.9.13 Not Used.

8.9.14 Facility shall be available to monitor the events on-line on a maintenance terminal. It should be possible to select the events, required to be monitored. All faults must have environmental data of pre and post initiation of the fault At least Two Maintenance terminals shall be provided as free supply item for each depot.

8.9.15 Separate CTs shall be provided for each inverter for measurement and protection functions.

8.9.16 Employer intends to maintain (both preventive and breakdown) the CI and other equipment in-house. All necessary tools, jigs/fixtures/hardware & software/test bench etc shall be provided by the Contractor.

8.9.17 The propulsion equipment shall ensure the guaranteed performance for wheel diameter differences

for at least up to 4 mm within any bogie without any adverse effect on any equipment. If the wheel diameter tolerances exceed the above limit, there shall be no damage to any equipment.

- 8.9.18 Power system fluctuations within the specified voltage range or feed extensions shall not cause propulsion system shutdown leading to jerks in the train. Adequate capacity shall be built in the DC link and control parameters shall be selected and fine tuned suitably so that in no case, system stability is adversely affected. The design shall permit to operate trains at 90 seconds headway with normal feeding zone of 15km and extended feeding zone of not less than 30km without any restriction. Contractor shall hire a reputed Power system analysis Design Consultant with the approval of Engineer and provision shall be made for arranging minimum three presentations by Consultant to Engineer.

Based on the operational requirements as above, Contractor shall furnish detail report on the minimum sub-station capacity required for adequate harmony with the all out mode operation of trains within the feeding zone, low frequency control stability to ensure no operational or reliability issue even if the specified headway and large number of trains in the same feeding zone, number of trains parked on the end depot with extended feed and resonance stability of the complete system.

- 8.9.19 The component cooling system shall be designed to ensure the control electronics temperature inside Converter-inverter/ auxiliary converter-inverter never exceeds 70°C under specified conditions after due consideration of proximity effect. The Contractor shall note that the air intake temperature for cooling can be appreciably higher than outside ambient temperature. The type measurements shall be normalized for maximum specified temperature.
- 8.9.20 For maintenance purpose, there shall be additional by pass ground switch in CI box duly interlocked with safety locks. Contractor shall submit the detail document for Engineer's review during design stage.
- 8.9.21 LED based lighting arrangement shall be provided in the CI box for maintenance purpose. Its fail safe interlocking with the box cover shall be ensured. Contractor shall submit the detail document for Engineer's review during design stage.

#### 8.10 AC Traction Motor

- 8.10.1 Three phase asynchronous traction motors, suitable for the proposed converter/inverter operation shall be offered. The motor shall have adequate built in margin to cater to the environmental conditions given in the specification. The motor shall be designed to suit ripples and harmonics from the inverter and shall have a high degree of reliability in service during motoring as well as regeneration.
- 8.10.2 The traction motor shall be self ventilated and shall comply with the requirements of IEC60349-2- 'Electronic converter – fed alternating current motors". An effective and efficient filtration system shall be provided to remove dirt and water from the self-ventilated traction motor cooling air. The air inlet openings shall include a protective screen designed in such a way as to preclude the accumulation of leaves and debris. If installed, filters shall require cleaning no more frequent than once every two weeks. Any sensor(s) if used shall be easily accessible for replacement and shall not necessitate removal of motor / its dis-assembly. Speed sensors if used shall not generally be placed on the gear case.
- 8.10.3 Evaluation of the insulation system for sealing against moisture shall be made in accordance with IEEE 429. The insulation system shall be evaluated for thermal endurance in accordance with the requirements of IEC 60505 (1975), its draft supplement and IEEE 304.
- 8.10.4 Various ageing parameters viz., thermal and electrical stresses, ambient temperature, humidity, dust and mechanical stresses, vibration etc., should be used in the evaluation and the temperature index of the insulation system corresponding to an extrapolated life of 20000 hours shall be established.
- 8.10.5 Traction motor design shall be based on following premises:

The RMS current of Traction Motor shall be calculated for all out run in the specified sections without stoppage (dwell) time.

The temperature rise limit for the stator winding shall be the maximum temperature index of the insulation minus 70°C and as indicated in clause 8.10.4 above under all operational conditions defined in Chapter 3.

The temperature rise shall be verified in system type test bed and the lines (as available) with 25% ventilation blocked. Contractor shall consider the temperature rise on account of different factors



- including proximity impact (not less than 10°C) in the underframe and specified wheel diameter difference in the bogie(s) as indicated in clause 8.9.17 above. The type test procedure and validation of temperature rise is described in Chapter 15.
- 8.10.6 The traction motor shall be suitably rated to meet the most severe service requirements as specified in design parameter Clauses 3.22.7 and 3.22.8.
- 8.10.7 The motor bearing maintenance inspection interval (excluding lubrication if required) shall exceed 1.2 million kilometres and the insulated bearing shall have a design life of minimum 2.1 million kilometres. Lubrication of motor and gearbox bearings shall be accessible without the need of equipment removal. Calculations supporting the choice of bearings shall be submitted for review. Minimum four traction motors shall be fully wired on four different trains (one Traction Motor on each train) fully equipped with data logger for data recording and sensors/thermocouples. The data loggers shall be able to record temperatures and vibrations at various points of traction motor at different speeds. The detailed locations of sensors in traction motors shall be as per the test bed scheme which shall be finalised during design stage.
- 8.10.8 The motor shall be mounted on the bogie frame via flexible coupling and gear unit, which shall be totally enclosed and free from lubricant leakage.
- 8.10.9 The grease used for the traction motor bearings shall be selected so as to ensure the expected maintenance interval considering the maximum temperature estimated to be reached in the bearings, under the worst conditions. It should be possible to replenish the grease periodically in situ and overflow arrangement should be provided to avoid the possibility of the over greasing.
- 8.10.10 The traction motors shall be designed for a life of thirty five years with no need for major overhaul before 1,000,000 kms.
- 8.10.11 The traction motor shall be connected to the single stage/double stage gear unit through a flexible coupling. The coupling design and the motor to gear unit mounting arrangement shall minimize coupling dynamic angular displacement. The motor shall be dynamic balanced. The gaskets shall be of suitable material, compatible for use with gear case oil and service life shall be more than 1,000,000 kms.
- 8.10.12 Each traction motor shall be provided with redundant thermistor for determination of temperature of stator winding. It should be possible to replace the thermistors in the depot without lifting the car. Traction motor terminal boxes shall be provided with heat-detectors/LHD linked to TCMS/fire detection & control unit (refer ERTS clause 2.20) so that their status is monitored.
- 8.10.13 Filters shall be of adequate size and cleaning interval of the motor shall be more than 6 months of train service. Cleaning of the filters shall be simple and Contractor shall suggest necessary equipment required for cleaning of filters and sanitization against fungal growth etc. Contractor shall provide minimum two sets of filter's cleaning equipment in each depot. Contractor shall also provide at least two no. of suitable equipment in each depot with provision of camera to determine the blockage in air cooling path for cleaning of filters. The cost of these equipment shall be deemed to be included in the quoted price of the contract.
- 8.10.14 Special attachment required for cleaning of air duct holes in the core shall be supplied for each depot. Cleaning frequency shall be more than one year and it shall be possible to undertake cleaning in-situ.
- 8.10.15 Motors shall be provided with noise mufflers or take alternative measures for minimising noise emission from motor.
- 8.10.16 In-situ traction motor cleaning arrangement/fixture capable of sucking dust from rotor and stator shall be provided to each depot. Additionally, cleaning arrangement for disassembled traction motor during major overhaul shall also be provided to each Depot.
- 8.10.17 In the event of train getting immobilised on line due to mechanical problems like bearing seizure, gearbox or axle defect etc., suitable arrangement shall be provided like wheel skate or similar device to quickly and safely transfer the train to the Depot. Suitable jacking points shall be provided beneath the axle boxes for enabling the placement of wheel skate. At least one such equipment shall be provided in each Depot.
- 8.10.18 AC traction motors shall comply with the requirements of Relevant standards i.e. IEC 60349-1, 60349-2, IEC 60349-3. Information on all the characteristics of the AC traction motor as stated in IEC 60349-2 shall be provided.
- 8.10.19 Any inspection covers provided shall be robust and designed for quick and easy removal /replacement and have secondary retention to prevent dropping. Inspection openings shall be as large as possible to facilitate inspection and maintenance.



- 8.10.20 The gearbox design shall give due consideration to minimizing weight.
- 8.10.21 The coupling of the gearbox shall accommodate all relative movements between the motor and the gearbox, including that caused by a free standing bogie, without damage to coupling.
- 8.10.22 The design of the motor installation shall permit the motor to be removed from, and refitted to, the bogie from above, without any need to disturb the axle and any bogie mounted equipment.
- 8.10.23 Where cables pass through holes in the traction motor frame, oil resistant resilient bushes suitably clamped shall be provided to prevent chafing of cables and to seal against the ingress of oil and water. The cables shall have sufficient freedom of movement to prevent stressing or fouling of other equipment during the full envelope movement of the bogie
- 8.10.24 There shall not be any permanent flying lead attached to the motor. All connections to the motor shall be bolted, torque tightened and marked.
- 8.10.25 Traction motors shall be fully interchangeable. All components requiring periodic replacement, whether mechanical or electrical, shall be fully interchangeable unless approved by the Engineer

### 8.11 Neutral Section Detection

- 8.11.1 A suitable arrangement shall be made to switch off the VCB automatically before a neutral section, resulting in the traction control equipment switching OFF without train operator's intervention. The VCB shall automatically re-close after the neutral section within bare minimum time, causing traction control equipment to switch ON again in the same operating mode, as before the switching OFF operation, without Train Operator's intervention. The sequence of VCB closure shall be such that not more than one unit is affected. Sequential opening and closing of VCB shall be ensured to minimize the power loss. Back up operation (both open and close) of VCBs of each unit shall be affected based on distance from the previous station.
- 8.11.2 The control logic for the neutral section detection shall ensure that the power demand smoothly reduces on approach to overhead line neutral sections and smoothly increases the power demand immediately after the neutral section under both normal and backup operation. Power ramping characteristics shall be submitted for review by the Engineer, and shall be validated by test.
- 8.11.3 Adequate redundancy shall be built in so that no single point failure can cause disruption. The status as well as failures of vital components shall be logged by TCMS.
- 8.11.4 There shall be complete TCMS backup arrangement for opening and closing of VCB before and after the neutral section meeting this functionality as stipulated in 8.11. Location of neutral section shall be made as an adjustable parameter in the TCMS Neutral section logic which could be edited by maintenance personnel. Contractor shall provide training to maintenance personnel in this regard.
- 8.11.5 Deleted.
- 8.11.6 In order to ensure VCB opening, distance based system for its operation during entry and exit of Neutral section shall be provided.
- 8.11.7 Signalling system shall provide a signal for operation on neutral section. Scope of provision would fall under the purview of Interface document Appendix TD.



**8.12 Deliverables**

8.12.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S. No.	Clause No.	Tools/Equipment/Software	Quantity
1.	8.2.12	On board setup for monitoring, recording & analysing pantograph current collection performance.	One set for each depot.
2.	8.2.17	Wayside measurement device for measurement of carbon strip width of pantograph and complete roof body inspection for any external agents (if any) during entry /exit point in the depot.	One set at nominated depot.
3.	8.7.15	Suitable oil filling equipment, complete with centrifuging, oil testing and other accessories for main transformer.	In each depot.
4.	8.9.12(i)	Test equipment as per clause 8.9.12(i).	One set at each depot.
5.	8.9.14	Facility to monitor the events of propulsion system on-line on a maintenance terminal.	At least Two maintenance terminal for each depot.
6.	8.9.16	All necessary tools, jigs/fixtures/hardware & software/test bench required for in-house maintenance (both preventive and breakdown) of the CI and other equipment.	One set at each depot.
7.	8.10.13	Filter cleaning equipment for traction motor.  Suitable equipment with provision of camera to determine the blockage in air cooling path for cleaning of filters.	Minimum two sets of in each depot.
8.	8.10.14	Special attachment required for cleaning of air duct holes in the core.	In each depot.
9.	8.10.16	In-situ Traction motor cleaning arrangement/fixture as per clause 8.10.16	In each depot.
10.	8.10.17	Suitable arrangement like wheel skate or similar device to quickly and safely transfer the train to the Depot.	At least one such equipment in each depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

## 9. AUXILIARY SUPPLY EQUIPMENT

### 9.1 Auxiliary Supply System

- 9.1.1 Auxiliary power supply shall be provided on a three-car unit basis. This shall consist of a static converter-inverter(s) together with back-up batteries and battery charger. Auxiliary Converter-Inverter shall be suitable for operation at 25kV AC single phase for the frequency variation from 47 to 53 Hz. The failure of auxiliary power supply equipment shall be annunciate to the train operator in TCMS VDU/OCC. Failure/isolation of main converter shall not cause any reduction in performance of auxiliary converter-inverter.
- 9.1.2 The auxiliary power supply system shall be configured such that it performs reliably for all operating train consists. Full auxiliary power shall be available from 19kV to 31kV.
- 9.1.3 The auxiliary power distribution scheme shall be such configured that each 3-car unit (1DM +1T + 1M) has at least one auxiliary power supply equipment. When any Train Operator's cab is activated, all the auxiliary power supply equipment in the train shall operate. In the event of failure of an auxiliary power supply equipment on one 3 car unit in 6 car train, the remaining 3 car unit auxiliary power supply equipment must be capable of supplying all auxiliary power to complete 6-car train except for HVAC load which shall work at 50% of the rated capacity.
- In case of addition of one (T+M) unit (if required), provision of auxiliary supply during different emergency conditions to and fro between 'T+M' unit and existing 3-car units shall be finalized during design stage.
- 9.1.4 While traversing the neutral section or in the event of momentary non-availability of OHE during service the lights shall work normally. Contactor shall finalize the design during Pre-Final Design Stage.
- 9.1.5 In case of addition of one (T+M) unit (if required), the ratings of Auxiliary equipment like Auxiliary Converter- Inverter, Battery, Battery charger etc. shall be same as that of existing 6 car train.

### 9.2 Auxiliary Converter-Inverter

- 9.2.1 The static type auxiliary converter-inverter shall be of latest metro transit-proven energy efficient technology (IGBT/SiC or latest) with microprocessor based, pulse width modulation control. The auxiliary converter-inverter shall receive its power from a separate winding in the Traction Transformer. The three-output voltage shall be as follows:
- (i) Output 1: 415V 50Hz 3 $\phi$  3 wire
  - (ii) Output 2: 230V 50Hz 1 $\phi$
  - (iii) Output 3: 110V DC
- None of the above shall be accessible by passengers.
- 9.2.2 The auxiliary converter-inverter shall be capable of maintaining full output over the traction voltage supplied range specified and also for the frequency variation from 47 to 53 Hz.
- 9.2.3 Power semiconductors shall be mounted on grounded heat sinks. Under all normal and emergency operating conditions, the peak junction temperatures shall not exceed 90% of their declared peak ratings. Natural or forced cooling can be offered but natural cooling is preferred. However, if forced cooling is offered complete details of the arrangement including the method of dust filtration shall be furnished.
- 9.2.4 The output circuits are galvanically isolated from the input and each other. The auxiliary converter-inverter shall provide power supply to all auxiliaries including ventilation blower motor, air-conditioning units, air compressor, doors, light equipment, control units and low voltage loads.
- 9.2.5 The supply shall be regulated within  $\pm 5\%$  of the nominal voltage and total harmonic disturbance shall be limited to 8% under all operating conditions. Phase-to-phase voltage imbalance shall not exceed 1% between phases. The converter-inverter shall otherwise comply with the provisions of IEC 61287-1.
- 9.2.6 The auxiliary converter-inverter shall be continuously rated to provide full auxiliary load on one 3 car unit (DM+T+M) plus other loads specified in clause 9.1.



- 9.2.7 Staggered starting shall be provided between auxiliary power supplies on the train to minimize start up loads.
- 9.2.8 Protection and diagnostics:
- (i) Control circuit logic shall permit testing and monitoring of the operation of the auxiliary power supply system when running.
  - (ii) Protection against single phasing and short-circuiting shall be incorporated into the auxiliary converter-inverter feeding 415V, 50Hz auxiliary drives.
  - (iii) The auxiliary power control system shall carry out self-tests to ensure the integrity of the equipment. Sufficiently detailed status, fault and diagnostic information shall be transmitted to the train integration management system (TCMS), to enable protective or corrective action to be taken immediately, when necessary.
  - (iv) The auxiliary converter-inverter shall use a control scheme that contains extensive self-diagnostic logic, which shall be fully integrated with TCMS. At a minimum, the diagnostics system shall identify a range of credible faults, identify whether a Least Replaceable Unit (LRU) is responsible for the fault, and whether the LRUs (or non-LRUs) must be replaced or the system merely reset. The diagnostics system memory shall be retained for at least 400 events.
  - (v) On the condition that the auxiliary converter-inverter has been started previously, in the event of an interruption of the primary power supply including loss of contact of pantograph with catenary, the auxiliary converter-inverter shall automatically re-start once the input power has been re-established.
  - (vi) The Train Operator from the cab shall be able to isolate any defective auxiliary power supply equipment.
  - (vii) All auxiliary power equipment shall be easily accessible for inspection, testing and maintenance.
  - (viii) Contactors shall be rated for maximum current capacity and overload interruption capability.
  - (ix) Protection scheme for Static Converter (auxiliary converter-inverter shall include but not limited to:
    - Over current detector
    - Over voltage detector
    - Converter fault output
    - Over temperature of semiconductor
    - Single phase detector
    - Inverter fault output
    - AC over voltage detector
    - AC low voltage detector
    - AC over load current detector
    - AC output short circuit current detector
    - Control power supply failure
    - Over voltage of inverter circuit
    - Over current of inverter circuit
    - Synchronous fault detector
    - Starting failure
    - Ground fault detector
    - DC over voltage detector
    - DC over current detector

The settings and calculations of above mentioned protections shall be discussed during Pre-Final Design Stage.

- 9.2.9 The box for auxiliary converter-inverter shall be such that to avoid any corrosion throughout the

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service life on any account and the box shall last for the lifetime of the auxiliary converter-inverter unit without needing any attention. The box shall be of stainless steel/anodized aluminium. The box cover which may have to be removed for maintenance shall be suitable secured against falling. Hinged opening cover arrangement shall be preferred.

- 9.2.10 Industrial 415V 50Hz 3 $\phi$  socket outlets with spring loaded covers, capable of accepting a shore supply shall be provided on each unit at sole-bar level, on both sides. Each shall be accompanied by a red lamp, to warn of live sockets, when a shore supply is plugged in. The control logic shall ensure that train power up is not possible when shore supply is applied to the train. The design and type of the interface connector shall be submitted to the Engineer for review. Minimum 50 numbers of the mating connectors shall be supplied for installation in each Depot.
- 9.2.11 The shore supply shall have sufficient capacity, rating and provision to enable Employer's maintenance personnel to test all electrical auxiliary equipment in three-car unit. The shore supply connector of adequate capacity shall be provided at diametrically opposite convenient locations on either side of each unit.
- 9.2.12 Additionally, internal 230V 50Hz 1 $\phi$  socket outlets for vacuum cleaners, and others loads (minimum two per car and one in driving console) shall be provided in each car. Separate 230V sockets shall be provided (on both ends near the last row of seats) for Mobile/PC charging.
- 9.2.13 For maintenance purpose, there shall be additional by pass ground switch in SIV box duly interlocked with safety locks. Contractor shall submit the detail document for Engineer's review during design stage.
- 9.2.14 Heat detectors/LHD in SIV and battery charger shall be provided and status shall be linked to TCMS/Fire detection & Control unit (refer ERTS clause 2.20) so that their status is monitored.
- 9.2.15 LED based lighting arrangement shall be provided in the SIV box for maintenance purpose. Its failsafe interlocking with the box cover shall be ensured. Contractor shall submit the detail document for Engineer's review during design stage.
- 9.2.16 All auxiliary converter-inverters shall be identical, interchangeable and under frame mounted. All internal items of the equipment shall be easily accessible and detachable, with the converter-inverter "in situ", to facilitate maintenance.
- 9.2.17 Input power factor of auxiliary converter-inverter shall be near unity under all load conditions. Under no condition it shall behave as capacitive and export reactive kVAR into the system.

### 9.3 Battery Charger

- 9.3.1 The battery shall be charged from the local (three-car unit) static battery charger. The battery charger with automatic control shall be capable of providing a temperature compensated high rate boost charge or float charge compatible with the characteristic of the Ni-Cd batteries.
- 9.3.2 The battery charger shall be capable of charging a discharged battery to 80% full charge within 4 hours. Once the battery is fully charged, float charge should stop after 10 minutes.
- 9.3.3 Batteries shall be connected to a common Battery Bus throughout the train.

### 9.4 Back-up Batteries

- 9.4.1 Each three-car unit shall be equipped with a battery set consisting of nickel cadmium cells having a nominal voltage of 110V with PP cell casings. The battery shall be rated and tested in accordance with the requirements of IEC 60623 and shall also meet the requirements of IEC 60993 and EN 50547.
- 9.4.2 The backup battery shall utilise a sufficient number of cells to ensure that it is capable of:
- Maintaining full DC loads when the train runs over neutral sections of the overhead line in case of 25 kV AC system.
  - Supply emergency load for at least 60 minutes (with doors open and close every two minutes) in case of failure of battery charger or its supply with the battery charged to a level as expected during service but not better than 80% of its full capacity. Contractor shall also demonstrate that at any time of service, stage of charge shall not be less than 80%, before the voltage level at any device



- falls below 77V DC Non-essential load shall be shed after 30 seconds of failure of battery charge supply. This feature shall be demonstrated during testing.
- 9.4.3 Emergency loads shall include, but need not be limited to:
- i. Emergency lighting.
  - ii. All exterior lights.
  - iii. Ventilation fans but not air conditioning.
  - iv. Communication systems including public address, passenger emergency alarm, surveillance system and train radio.
  - v. Propulsion and brake controls.
  - vi. Door controls.
  - vii. TCMS.
  - viii. Electric horn.
  - ix. Driving console indicators, lighting and interlocking.
  - x. ATP train borne equipment.
- 9.4.4 The design and control of the battery shall ensure that there is sufficient capacity left under all conditions to raise all the pantographs simultaneously. Adequate circuit protection shall be provided to ensure the battery load shall be disconnected when the battery voltage has dropped below 70% of the nominal voltage and when the auxiliary load is re-connected, the initial battery load shall not cause the battery output to oscillate.
- 9.4.5 Battery electrolyte capacity shall be such that the batteries will not require topping up more than once in a year. Complete calculation of loss of water and float/boost charging shall be submitted. Batteries shall be designed with integrated topping up provisions. Suitable interconnection shall be provided so that topping up of all the cells can be carried out using from a single point on battery box. The design shall be submitted for review of the Engineer.
- For the calculation of sizing of battery at high and low temperature, ageing de-rating factor and charging de-rating factor shall be considered and calculations shall be submitted to Engineer during detailed design stage.
- 9.4.6 The battery terminal voltage shall float on the 110V DC output of the auxiliary power supply of which the output voltage shall have fine adjustments and good stability to avoid over or undercharging of the battery.
- 9.4.7 The control elements taking power from the battery shall be capable of operating between 77V and 138V DC. The instantaneous battery voltage shall be monitored and recorded through TCMS.
- 9.4.8 Deleted.
- 9.4.9 One set of battery electrolyte automatic topping up devices shall be provided for each Depot. These devices shall be portable and easily operated by one person. They shall incorporate a feature to cut-off the electrolyte automatically when it has reached the correct level.
- 9.4.10 Two trains (one on each line) shall be fitted with Battery Control and Monitoring Unit (BCMU) to monitor the charging, discharging current, voltage etc. It shall be possible to install the BCMUs in any of the trainsets at later stage.
- 9.4.11 Battery Protection and Isolation:
- (i) Battery fuses of suitable rating shall be fitted in a separate box located adjacent to one of the battery boxes and shall enable easy access from track level.
  - (ii) Back connected fuse holders shall be provided and the battery fuse enclosure shall be sealed to IP65 in accordance with IEC 60529.
  - (iii) A battery contactor operable from inside the cab shall be provided to disconnect the battery from the car wiring electrically, when required.
  - (iv) A low voltage earth bar shall be provided and located close to the negative fuse.
  - (v) The status of fuse and circuit breakers shall be monitored by TCMS.
- 9.4.12 Battery temperature shall be displayed in TCMS.

**9.5 Battery Box**

- 9.5.1 The box for battery shall be such that to avoid any corrosion throughout the service life on any account and the box shall last for the lifetime of the cars. Within the battery box, the battery shall be mounted in roll out trays to allow for easy maintenance.
- 9.5.2 The roll out system shall be corrosion resistant, and shall be provided with the necessary stops and locks to limit the travel of the battery box and retain it in both extreme positions. When rolled out, the entire top of the battery shall be exposed. All the battery terminals, including battery positive and negative main connections shall be easily accessible for maintenance work.
- 9.5.3 The box interior / the roll out trays shall be lined with a non-flammable, electrolyte proof, insulating material of suitable thickness. The box shall be ventilated to preclude the possibility of built-up of any gas. Vibration proof automatic lock shall be provided to ensure absolutely no relative movement of the batteries inside the tray.
- 9.5.4 The battery box shall be sized to have at least 10% extra space to accommodate augmented capacity battery. Extra space shall be suitably packed.
- 9.5.5 Battery box shall not deshape/sag during lifetime of the car. Adequate strength shall be built in the battery box by providing suitable ribs etc. FEM & fatigue report of the battery box shall be submitted to establish the same.

**9.6 Inverter for HVAC Ventilation**

- 9.6.1 Adequately sized DC inverter shall be provided in the underframe/inside HVAC unit to feed the ventilation fans of both the HVACs of each car.

**9.7 Deliverables**

- 9.7.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	9.2.10	Mating connectors for shore supply installation.	Minimum 50 numbers in each depot.
2.	9.4.8	Battery electrolyte automatic topping up devices.	One set for each depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



## 10. TRAIN CONTROL MANAGEMENT SYSTEM

### 10.1 General

#### 10.1.1 Features

All the trains shall be equipped with microprocessor based Train Control Management System (TCMS) providing real-time distributed control and modular processing of all sub-systems in fully redundant manner with high reliability and availability required in adverse operating environment experienced in MRTS system.

TCMS shall be a completely integrated system equipped with

- i) data acquisition,
- ii) monitoring,
- iii) control,
- iv) record,
- v) display,
- vi) self-diagnostic,
- vii) fault diagnostic,
- viii) remote diagnostic,
- ix) configuration editing,
- x) troubleshooting-guidance

features/functions for the train, its systems and subsystems. Contractor shall submit a comprehensive list of capabilities for each of the above listed features.

#### 10.1.2 Proven Design

Basic architecture and hardware of TCMS proposed to be implemented/used by the Contractor should already be functioning in Metros since last more than two years and shall be compliant with international norms. The Contractor shall submit basic system architecture with hardware for approval at the concept design approval stage and establish 'proven design' as specified.

#### 10.1.3 Maximise Controls & Monitoring via TCMS

It is desirable that the control and monitoring functions are implemented by software, to the extent possible, so as to reduce hardware and cables. All functionalities that can be implemented by software shall be provided via TCMS unless specifically desired otherwise by the Engineer.

#### 10.1.4 Deputation of Employer's Engineers

During the development of TCMS for the project, the Engineer shall depute a team of Persons to fully associate with the TCMS/controls design work so as to make them competent to implement software changes as required within the scope of this contract. Contractor shall ensure full association and support of Contractor/Sub-Contractor's design team with the Engineer's team throughout the project or as the case may be.

#### 10.1.5 SIL Compliance

TCMS shall be SIL2 compliant for all vital and safety related control and monitoring functions including but not limited to the following hardware, software and control functions-

- VATC (Vehicle Automatic Train Control) operation mode (ATP, ATO and UTO etc.),
- Door Proving loop cut-out,
- PWM transmission (communication),
- PWM signal (Hardware) failure,
- Door Open Push Button,
- Direction control of train operation,
- Holding brake release,
- Speed transmission,
- Fire alarm transmission via VATC,

- ED (Electro Dynamic) brake cut-out signal transmission,
- Actual ED brake effort signal transmission,
- Sliding signal transmission,
- ED brake effective signal transmission,
- Holding Brake demand signal transmission,
- Holding Brake applied status transmission;

at all levels including but not limited to hardware, software and control functionality etc. Any change in SIL level shall be subject to the hazard analysis and acceptance or otherwise of the same by the Engineer, whose decision shall be final and binding.

#### 10.1.6 UTO Compatibility

The TCMS architecture, functionality and redundancy level shall be compatible with the UTO mode of operation. Contractor shall submit details of all UTO specific design functionalities for Engineer's review.

#### 10.1.7 Signalling Interface

TCMS shall have adequate facility and interfaces to communicate with wayside signalling for both UTO and non-UTO modes. It shall be possible to simultaneously operate different trains in a section in GoA2/GoA3/GoA4 without any safety/reliability issue as per IEC 62290-1:2006.

#### 10.1.8 TCMS Configuration Details

The Contractor shall submit the complete TCMS configuration details including but not limited to Application Software Logic, Data Acquisition Routines, Control logic, Fault Detection Algorithms, Data Storage Logic etc. Graphical interface for editing and configuring the same shall be provided and submitted for Engineer's approval during design stage.

#### 10.1.9 Applicable Norms and Standards

All communication protocols, architecture and data acquisition concepts shall be of the latest state of the art technology and compliant to international and railway industry standards. The Tenderer shall advise the proposed applicable standards for review.

#### 10.1.10 Conceptual Approval Only

Design approval of proposed TCMS shall imply only conceptual approval. Further changes as required by Engineer based on operational, maintenance and functionality considerations shall be discussed during the contract and solution be implemented to the satisfaction of Engineer without additional cost. This will include finalization of event list, fault priorities, diagnostics and others.

#### 10.1.11 The cables which are intended to be used in emergency circuit for alarms and communication shall have intrinsic fire resistant property in compliance with EN 50200.

### 10.2 TCMS Architecture

#### 10.2.1 Data Communication Link

##### i) Ethernet based

The network communication technology to be adopted for all TCMS data communication links and subsystem communication interfaces shall be based on Ethernet (100 Base TX or better).

##### ii) EMI Immune

Proven train data communication links that are immune to EMI and harmonics generated by traction equipment shall be provided between the cars. Suitable physical bus interfaces, to ensure error-free and high speed data transmission shall be provided.

#### 10.2.2 Ethernet Train Backbone (ETB)

Ethernet-based Train Backbone with redundant Train Backbone Nodes (TBNs) (at least two in each consist network) shall be provided to achieve interoperability between consists when coupled in the train as per IEC 61375-2-5.

The data transmission medium in Ethernet-based Train Backbone shall be doubled to support redundancy.



It shall be possible that number and type of connected consist networks in existing 6-car train can vary during operation by insertion of one "T+M" unit in the middle of the train to form a 8-car train in future as per Para 5.3: Train Compositions of IEC 61375-1.

#### 10.2.3 Ethernet Consist Network (ECN)

Ethernet Consist Network with dual-homing ladder-type topology/dual-homing ring-type topology (compliant with IEC 61375-3-4) shall be adopted. The ECN shall maintain redundant communication links to the ETB.

#### 10.2.4 Dual-Homing End Devices (ED)

All the End Devices shall support dual-homing type Ethernet connections to ECN via physically independent ports to increase system reliability and availability.

All digital and analog IOs interfacing with TCMS (directly or via an interface unit) shall also be fully redundant.

#### 10.2.5 Redundant Processors

The processors running the TCMS application software for control, monitoring etc. shall be duplicated with a hot standby redundancy provision. Details for the switchover and recovery times shall be submitted by the Contractor for Engineer's review.

#### 10.2.6 Single Point Failure Tolerant

The TCMS shall be of fault tolerant distributed control system architecture. A single point failure of any individual equipment/component/board/communication link etc. shall not affect data acquisition & processing or cause any adverse performance impact on train performance or loss of data.

Contractor shall submit the failure redundancy matrix for entire TCMS indicating the various failure modes, available redundancies and the effect on train performance.

#### 10.2.7 Spares Provision

The TCMS components shall be modular in design at all levels (i.e. hardware, functional, communication etc.) with at least 10% spare capacity in each car for expansion at the end of DLP. The spare provision shall exist for all different equipment's pins, terminals, connectors, ports, train lines, communication packets bits, digital/analog IOs etc. and the same shall be available for after DLP. The hardware spares shall be duly wired to the nearest terminal box.

Considering that some changes/modifications would be required during DLP, at least 12.5% spares capacity shall be initially ensured by Contractor.

Contractor shall submit a detailed proposal for Engineers review and approval during design stage.

#### 10.2.8 Expandability Provision

The Contractor shall also provide 10% expandability provision (i.e. expansion of capacity by adding of additional hardware) for pins, connectors, network ports, PCB cards, train lines etc. over and above the spares available at the end of DLP. Contractor shall demonstrate to the Engineer that adequate space has been reserved to exercise this option.

#### 10.2.9 IEC 60571 Compliant

The hardware system shall conform to IEC 60571.

#### 10.2.10 IP Rating

Minimum IP level of all TCMS cubicles/equipment or the panel in which it is installed shall be IP53 or higher and the same shall be declared by the Tenderer.

#### 10.2.11 Labelling

The type, location and identification of all hardware, software interconnections, cabling and terminals shall be determined on a coherent hierarchical system basis. Labelling or identification shall use appropriate English language based mnemonics or abbreviations. The Contractor shall submit proposal for review.

#### 10.2.12 Maximum CPU Loading

Contractor shall demonstrate to the Engineer's satisfaction that none of the TCMS CPUs/processors are loaded to more than 50% of their processing capacity. The Contractor shall

keep adequate margins in the design to allow for addition of functionalities to TCMS during DLP period. A verification report for the same shall be submitted.

### 10.3 Data Acquisition

#### 10.3.1 Network Interfaced Systems

TCMS shall schedule, initiate and control data acquisition, processing and analysis by interfacing with all microprocessor/ microcontroller based on-board systems. These systems shall include, as a minimum:

- i) ATP/ATO,
- ii) HVAC System,
- iii) Auxiliary Power Supply System,
- iv) Brake System,
- v) On-Board Communication System,
- vi) Doors,
- vii) Propulsion System,
- viii) Train Radio,
- ix) PSSS (Passenger Saloon Surveillance System),
- x) Lighting System,
- xi) Wayside Wireless Communication,
- xii) Fire Detection Unit.

All interface signals with ATP/ATO and selected interface signals with other on-board systems shall be monitored and recorded with time stamp. The Contractor shall submit the details for Engineer's review.

#### 10.3.2 Hardwire Inputs

In addition to above, TCMS will also acquire status data via hardwire from the various identified vehicle control circuit nodes, train lines, ATP/ATO, or any other subsystems. This data acquisition shall be fully redundant, bus monitored and duly recorded in TCMS. The interface units provided for this purpose shall be dual homing compliant.

#### 10.3.3 Communication Protocol Details

The software and communication protocols used throughout the TCMS and the interfaces to subsystems shall be compliant to a common standard or standards. Contractor shall submit details of the communication protocols used in their design (at all different levels of the OSI model) clearly indicating how the requirements of monitoring and control are complied with. The Contractor shall also define the dual-homing compliant communication protocols for all EDs. Further details along with any hardware/software tools required shall be submitted during design stage.

#### 10.3.4 Signal List Modification

It shall be possible for authorized maintenance personnel to update and modify the list of data acquisition signals and its associated parameters like periodicity, task cycle, data acquisition routine etc. Suitable graphical configuration editors shall be provided for this purpose.

#### 10.3.5 Clock Synchronisation

TCMS shall synchronize its clock with the system master clock through the ATP/ATO interface. All the microprocessor/microcontroller based on-board systems shall synchronize respective clocks with TCMS clock. Detailed clock synchronisation proposal shall be submitted for Engineer's approval.

### 10.4 Control Features

#### 10.4.1 Non-Vital Controls

TCMS shall be used to execute all non-vital commands and controls of the train.

#### 10.4.2 Vital Controls



TCMS shall be designed to provide back-up controls of certain identified vital commands. Unless otherwise indicated specifically in these specifications, hardware back up shall be provided for each safety related control functions.

#### 10.4.3 Control Strategy

The Contractor shall submit technical details of the TCMS control system with full explanation of control methods and strategy adopted in the design. The proposal shall also clearly discriminate between the implementation of vital & non-vital controls as well as manually triggered/operator-based & automatically executed controls.

#### 10.4.4 OCC Remote Controls

TCMS shall have provision for receiving and implementing remote control commands from OCC/DCC. Necessary interface with S&T Contractors shall be ensured.

#### 10.4.5 List of Operator Control Functions

Control features available for the Train Operator's control via on-board HMI or for the OCC/DCC's control via remote HMI shall include, but not be limited to, the following:

- i) Train start up.
- ii) Control of various saloon and cab air conditioner parameters such as selective and/or collective starting and switching off, car temperature control, provide override control of operating mode etc.
- iii) Isolation of any particular passenger side door that has been detected as closed and locked.
- iv) Override control over automatic selection of the saloon light circuit(s).
- v) Resetting of minor faults in sub-systems.
- vi) Provide a VCB control logic during Neutral section traversal as fully functional back up in all driving modes and directions.
- vii) Any other item as desired by the Engineer.

The Contractor shall submit detailed list of functions /features proposed to be controlled through TCMS for Engineer's review and approval.

#### 10.4.6 Protective Controls

TCMS shall appropriately shut down or reset equipment in response to self-diagnostic test results or occurrence of specified faults. Detailed scheme for protective controls shall be submitted for Engineer's review and approval.

#### 10.4.7 Speed Calibration Control

Automatic speed calibration through Doppler radar or better means shall be ensured specifically whenever wheel is turned and train is moving out of Depot for revenue service.

#### 10.4.8 Speed Sensor Redundancy

Adequate redundancy shall be built in for correct train speed measurements in case of failure of any of the speed sensor. System shall also counter check the speed recorded by the ATP/ATO. For this purpose, the Contractor shall suitably interface with Signalling Contractor.

#### 10.4.9 ATC Interfaced Controls

##### i) Remote Initialisation

TCMS shall interface with ATC for remote initialization of train at siding, stabling lines or in Depot for revenue operation. The "wake-up" command from OCC shall be implemented by TCMS after performing self-tests of different train borne systems. TCMS shall send train ok signal to train ATC else a corresponding fault code shall be sent.

##### ii) Sleep Control

ATC may initiate automatic train sleep function when trains are not required. Whenever sleep command is initiated by Train Operator, TCMS shall shutdown the relevant equipment except for control supply to necessary equipment.

##### iii) Standby Control

Train Standby function may be actuated by ATC system when train is in stabling siding. TCMS on

receipt of such command shall switch off auxiliary equipment except compressor, battery charger etc. and shall maintain train in a "Ready" state.

iv) Shunting Control

The shunting operation of train in depot shall be under GoA3/4 as initiated by ATC.

10.4.10 UTO/ATO Interface

TCMS shall be fully compatible and interface with signalling system to ensure safe UTO/ATO operation.

For UTO/ATO operation, the necessary train command digital inputs signals shall be provided by the Signalling Contractor. The ATP/ATO/UTO initiated signal demands shall be redundant. The redundancy shall also be provided on TCMS side by RS Contractor. The form of these inputs shall be coordinated between RS and Signalling Contractors.

The Contractor shall also liaise with the Signalling Contractor to harmonise his system with the energy saving modes under ATO/UTO.

**10.5 Driving Console Interface**

10.5.1 Visual Display Unit (VDU)

Each Driving Console shall be provided with a VDU to display real time information to the train operator. The VDU shall support both text and graphical presentation of information. Commands shall be entered by the train operator via touch screen. Suitable protection features for the safety of the VDU shall be provided.

10.5.2 VDU Display Information

The VDU shall display information related to, but not limited to, the following:

- i) Equipment operating status.
- ii) Faults and failure of both auxiliary and control functions.
- iii) Recommended remedial actions in the event of alarms or faults occurring on the train.
- iv) Time

All the screens shall display the time (24-hour format), date (dd/mm/yy), the train configuration and approximate number of passengers.

v) Odometer

A six-digit odometer to display recorded cumulative distance run by the unit, irrespective of direction.

vi) Energy Consumption Data

TCMS shall interface with the relevant sub-systems and shall provide the facility to display energy consumption for one sided/round trip as well as cumulative for each consist and for the train.

vii) Crew ID and Train ID

Facility shall be available to key in the Train Operator and Train Identification Number (in case same is not available through ATC interface).

viii) Train Speed

TCMS shall interface with the relevant sub-systems to reliably display and record the train speed.

ix) Push Button record

All operations of Train operator including pressing of push buttons etc. shall be recorded with time stamp and be made available on VDU.

x) Safety Switch Status

Status of safety switches shall be displayed on VDU and shall be acknowledged by the incoming train operator. The status shall be relayed to the Control centre through train radio.

10.5.3 VDU Screens Design

The VDU shall provide distinct screens for different functionality or subsystems. The information shall be divided among screens and presented in a logical and orderly manner. The screen layout



including the selection of default screen, abbreviations etc. shall be reviewed and approved by the Engineer.

#### 10.5.4 Editing VDU Screens

The format/no./ contents of VDU screens shall be proposed by the Contractor during design and may have to be changed during the contract based on operational/maintenance requirements. The Contractor shall make such changes as and when required by the Engineer during the contract and shall also train Employer's engineers to design, review and execute the changes in VDU screens in post contract period. Necessary hardware and software tools shall be provided for each Depot.

#### 10.5.5 VDU Access Control Levels

The level of access to distinct screens shall be controlled for the train operator and maintenance personnel. At least three levels shall be defined which shall be user name and password protected. The details shall be reviewed by the Engineer.

#### 10.5.6 Test Mode Extension of VDU

The TCMS VDU shall be connected to the Ethernet Train Bus and it shall be possible to simultaneously plug-in multiple laptops at any point on the train bus and replicate the TCMS VDU display. Suitable application software shall be developed to enable replication of TCMS VDU along with touch and/or mouse-based interaction. Such additional VDUs shall login as "Test Mode" that shall be provided in addition to the "Operator and "Maintainer" modes of the TCMS.

#### 10.5.7 VDU Hardware

Capacitive-touch screen based VDU or better shall be provided as approved by the Engineer. The display screen shall be of coloured Light Emitting Diode (LED) type, suitable for use in rugged railcar environment. VDU shall be equipped with brightness, sharpness, intensity and contrast controls etc.

#### 10.5.8 CCTV Display Redundancy

Full redundancy shall be available between VDU of TCMS and CCTV. In case of failure of TCMS VDU, full functionality of TCMS VDU shall be available in CCTV VDU and vice-versa. CCTV images can be displayed on the TCMS VDU on demand or event generated. The TCMS VDU shall have provision of displaying multiple screens as per the requirements.

#### 10.5.9 VDU Response Time

The response time for most complex VDU screen change from one TCMS screen to other TCMS screen, TCMS to CCTV screens, maneuvering from one camera image to other under full VDU loading including the conditions stipulated under 10.1.2 shall be approximately 0.5 seconds. Contactor shall submit compliance details during design stage which shall be got validated during line test.

### 10.6 Self-Diagnostic Features

#### 10.6.1 TCMS Self- Diagnostic Tests

The TCMS unit shall incorporate built-in self-test diagnostic functions. The results of these self-diagnoses shall be accessible on VDU and any failures shall trigger appropriate faults/alarms/protective action. Details of the same shall be submitted during design stage for Engineer's review.

#### 10.6.2 Subsystem Self-Diagnostic Tests

All the on-board microprocessor/microcontroller based subsystems shall also perform self-diagnostic tests and report the detailed health status to TCMS, both automatically and on specific request (using VDU) by maintenance personnel.

#### 10.6.3 Self-Diagnostic Tests

The self-diagnostic tests shall assess and report the health of boards, sensors, memory, watchdog timers, inputs, outputs, bus connectivity, PCB level components status, software, firmware etc. Hardware and software shall be provided for self-diagnostic test of the critical system functions. Detection of a failure shall cause an indication to be displayed on the VDU.

#### 10.6.4 Software Versioning



Time stamping of date of software(s) as well as version of software(s) used in different sub-systems of the train and their compatibility shall be ensured by TCMS. The details of version of software(s) used in different sub-systems with time of uploading shall be displayed at the TCMS at the time of Power Up (wake up). The system shall not permit loading of incompatible software(s). Manual override in certain cases can be permitted by the Engineer, details to be finalized during design stage.

## 10.7 Fault Diagnostic Features

### 10.7.1 Fault Diagnostic Function

TCMS shall perform the task of fault diagnostics, in addition to performing the control/monitoring tasks. The design shall consider the train as a complete system and diagnostic capability incorporated in the system shall detect any node or line section failure rapidly to ensure no impairment of normal control and monitoring functions. The Contractor shall submit proposed scheme and fault detection logic for Engineer's review and approval.

The fault diagnostic functionality of TCMS shall include, but not be limited to, the following features:

- i) continuously monitor the status and determine health of all connected equipment and subsystems,
- ii) detect and log events and fault occurrences,
- iii) perform fault analyses and perform failure management actions by,
- iv) causing appropriate action to be taken, and wherever necessary shut down affected equipment,
- v) present alarms & conditions/guidance to the train operator.

### 10.7.2 Fault Detection

Degraded performance condition monitoring shall be provided as an integral part of TCMS wherein on-board CPU shall process the inputs from on-board subsystems and be able to determine car level, unit level or train level faults based upon the defined fault parameters/detection logic.

The various important parameters/signals of the equipment/subsystems (i.e. associated trace/environment data) shall also be recorded for pre-determined period before and after of occurrence of associated events/faults with a view to enable proper fault analysis.

The key indicators of degraded performance, fault parameters/detection logic and trace data signals for all principal car systems shall be defined by the Contractor and reviewed by the Engineer.

### 10.7.3 Fault Analysis and Management

Appropriate corrective actions shall be taken to reset critical faults and guidance shall also be provided to operator in the form of Troubleshooting Directory (as defined in Section 10.8). Details of failure management actions shall be submitted during design stage for Engineer's review and approval.

### 10.7.4 Fault Info Display

Real-time diagnostic information shall be made accessible on the train VDU and the OCC GUI to assist the operator to operate the train safely, quickly, efficiently, and to rectify resettable faults or failures.

### 10.7.5 Fault Levels

The scheme proposed shall differentiate between faults which are not potentially life threatening (e.g. air conditioning failure) and other system faults which could be life threatening (e.g. failure of the brake system).

The faults/events shall be at three or more levels with 'Level 1' events displayed on HMI with buzzer, 'Level 2' events displayed on HMI without buzzer and 'Level 3' being events recorded in the memory.

### 10.7.6 Auto-upgradation of Frequent Faults

Provision shall exist to temporarily upgrade the level of the fault/event automatically in case of its being experienced for predetermined number of times (settable by the authorized maintenance



personnel) in pre-determined time period (settable by the authorized maintenance personnel). Detailed proposal for the same shall be submitted for Engineer's review and approval.

#### 10.7.7 Editing Fault Configuration Logic

Fault analysis and fault management algorithms, data acquisition routines and data storage logic shall be programmed and presented using Windows or equivalent user interface software and shall be fully editable by the Engineer.

Authorised maintenance personnel shall have facility to select and edit:

- i) event details (e.g. displayed fault text, fault level etc.),
- ii) list of associated parameters/trace data,
- iii) periodicity of the parameters/trace data,
- iv) time interval for pre and post event capture of parameters /trace data,
- v) fault detection algorithms and fault management logic.

Complete facilities to implement the same shall be supplied.

#### 10.7.8 Specific Fault Provisions

The following are some faults that shall necessarily be included in fault detection logic:

- i) Popping up and acknowledgement of the status of each safety switches not in normal state at the time of taking traction and cab activation.
- ii) Loss of redundancy of equipment and subsystems.

### 10.8 Troubleshooting Directory

#### 10.8.1 General

For quick guidance of Train operator and Maintenance staff, a summarised menu driven, user friendly Trouble Shooting Directory (TSD) shall be made available in the HMI. The TSD shall have separate login modes for operators and maintainers. Extensive use of graphics shall be made in TSD for better understanding of the T.O.'s. Details shall be decided during design & revenue service period.

#### 10.8.2 Maintainer Mode

- i) Highlighted FBD

The maintainer mode of TSD shall display detailed Functional Block Diagram (FBD) (as per IEC 61131) for the fault detection software logic wherein the relevant pathways of the logic diagram tree that triggered the fault shall be highlighted.

- ii) Input Output Signal State

The TSD shall also display the real-time states of the various input and output signals related to fault detection logic in tabular form.

- iii) Action Items

Detailed action item text containing description of fault logic, possible failed device(s) info, troubleshooting instructions and corrective action as collapsible blocks of text shall be included on TSD screen. This text shall be colour coded so as to indicate the most pertinent points for any particular failure.

- iv) Mode Switch

It shall be possible to switch from maintainer mode to operator mode of TSD without logging out of TCMS maintainer mode but not vice-versa.

#### 10.8.3 Operator Mode

- i) Graphics and Animations

The operator mode of TSD must include graphics and animations that shall be developed corresponding to all the failed devices, all the failure cause identifications and all the proposed corrective actions for each of the faults. These graphics shall be submitted for review of Engineer and shall be promptly updated as per his decision.

The detailed proposal for the same shall be submitted during design phase and shall include a listing of all media files being provided in the TSD library.

ii) Locational mapping

The locational mapping of these graphics files with various train equipment and various fault codes shall also be submitted. The colour highlights and transition effects possible with the graphics shall also be made part of the proposal.

10.8.4 Intelligent Analysis

The TSD shall be smart enough to group together related faults (i.e. faults that have the same root cause) and provide guidance in a combined view for such faults. The various FBD logical pathways as requested above shall be distinguished in this case with different colours.

10.8.5 Editing of TSD

Based on the operational requirements, the directory shall be regularly upgraded during the contract period. The TSD shall be editable by authorised maintenance personnel. Necessary training for the operator and maintenance personnel shall be provided.

**10.9 Maintenance Tools**

10.9.1 Scope of Supply

A minimum of ten notebook computers as approved by the Engineer, together with all associated accessories and preinstalled software necessary for all diagnostic and configuration editing functions for all train-borne equipment shall be provided. Two copies of all the software uploaded in the notebook computers shall also be provided separately in approved non-volatile memory.

The notebook computers shall be of rugged design, high performance having sufficiently large storage capacity, high battery backup, sufficient no. of ports required generally (like USB, LAN, serial, VGA, HDMI etc.), a DVD writer (inbuilt or separate) etc. with latest generation Processor and Operating System.

10.9.2 On-board Connectivity

A high-speed suitable communication port shall be provided in each car to interface with a notebook computer and all information on the TCMS shall be made accessible on the notebook computer. It shall be possible to download the desired data for the entire train including data logged in its subsystems through any one of these ports (single point downloading of train's faults/data).

Additionally, it shall also be possible to connect with TCMS remotely via wireless network access and download faults from any train on mainline or in depots.

10.9.3 Levels of Access

The level of access to distinct functionalities shall be controlled for the maintenance personnel. At least three levels shall be defined which shall be user name and password protected. The details shall be reviewed by the Engineer.

10.9.4 Required Features

The notebook computer shall provide full testing of and interaction with the on-board TCMS at both train and car level. The following minimum capabilities shall be provided:

- i) System monitoring, fault data retrieval and analysis,
- ii) Viewing and processing of logged TCMS data,
- iii) Uploading new operating software and parameters for all the on-train subsystems,
- iv) Uploading new train configuration data (e.g. wheel diameters, etc.),
- v) Downloading of fault and usage information,
- vi) Initiating self-test and Downloading self-test reports,
- vii) Exercising and checking of digital inputs and outputs,
- viii) Checking of train and subsystem serial links,
- ix) Checking of train data bus set-up and configuration,
- x) Retrieval of equipment identification numbers,



- xi) Initiating function testing of on-board equipment,
- xii) Force various inputs/outputs interfacing with VCC,
- xiii) Forcing internal signals of TCMS as a tool for simulation,
- xiv) Editing of fault logic (ERTS 10.7.7),
- xv) Editing data acquisition signal list (ERST 10.3.4),
- xvi) TCMS configuration editing (ERTS 10.1.8),
- xvii) Editing DR data signals list (ERTS 10.10.3),
- xviii) Accessing depot management software,
- xix) Accessing multiuser software,
- xx) Accessing fracas software,
- xxi) Accessing document management system software,
- xxii) Running Energy Saving mode analytical tools (ERTS 10.12.3).

#### 10.9.5 Single Point Upload/Download Provision

- i) Single point uploading of software and downloading of faults shall be possible from TCMS nodes and/or via wireless mode in each train. In-case of sub-supplier's equipment like doors, PIS, HVAC etc. also, single point uploading of software and downloading of faults on unit/car/train basis shall be ensured.
- ii) The overall time required for uploading the software and downloading fault data for all subsystems shall not be more than 15 minutes each and the same shall be demonstrated.
- iii) Contractor to ensure that all fault and associated data residing in the subsystem's internal memory shall be retrievable on specific request from the TCMS nodes/wireless terminal.
- iv) If fault data downloading is interrupted somehow, it should resume from the same point, at which it was interrupted.
- v) The trip specific data shall be dumped at the end of each trip. This data should be sent via radio network, for which suitable interface to be ensured with the designated Contractor.

#### 10.9.6 OS Compatibility and Upgradability

All the software(s) used in train, diagnostics, monitoring or analysis purpose shall be compatible with latest Windows version and upgradable for higher versions of Windows. The Contractor shall either commit to supply upgraded versions to match with higher version of Windows, as and when available or the software(s) shall be so developed to have automatic upgradability with Windows.

### 10.10 Recording Features

#### 10.10.1 Operator Commands Log

TCMS shall retain a non-volatile record of all train operators and ATP/ATO initiated commands and system responses for a minimum of 240 hours before overwriting. Overwriting shall be such that the latest information is retained.

#### 10.10.2 Event/Fault Information Log

Adequate redundancy shall be built into TCMS. The size of On-Board Database memory for fault records shall be sufficient to hold all car level and train level events (at least 10,000 events) between normal downloading intervals of 30 days through hardware download. In case of overwriting, 'Level 3' events/faults only may be overwritten.

#### 10.10.3 Data Recorder Log

Separate adequate sized memory shall be available in TCMS for keeping user defined data recording (DR) log files for extensive continuous data logging and fault analysis for more than 200 parameters/signals.

The list of parameters/signals and trigger conditions for recording start/stop shall be fully editable.

#### 10.10.4 S&T Interface Signals Logs

TCMS shall also log information/signals as received/delivered from/to ATP/ATO and Train Radio equipment supplied by the Signalling and Train Control Contractor and Telecommunications Contractor respectively. Please see Appendix TD for details.

The Contractor shall also enable Signalling Contractor to record similar data/signal interfaced between Rolling Stock and Signalling. During design and interface, additional signals may have to be interfaced with Signalling Contractor to improve train performance. The same shall be implemented by the Contractor.

#### 10.10.5 Memory Capacity Limit

For the functionalities specified in these specifications, not more than 70% of the provided memory capacity shall be utilized. Further all the memories used in TCMS shall be expandable further as required by the Employer.

#### 10.10.6 Event Recorder

##### i) Redundancy

Redundant event recorder compliant with GM/RT 2472:2002 shall be provided for the train. The event recorder shall be redundant to each other and shall be type tested to demonstrate the integrity of recorded data and ability to extract data following an incidence.

##### ii) Capacity

The recorder shall have the provision of recording at least 200 signals of the data which should be easily retrievable either by directly connecting the Window based PC or/and the storage media shall be removable type. The recorder shall have capacity for 24 hours recording of selected data. The recording shall be on a non-volatile memory capable of retaining the recorded data with time stamp and location for at least 15 days.

##### iii) Integrity

The Recorder shall be fully protected against illegal tempering, shall maintain its structural integrity and integrity/retrieval of data/device during accident.

Further details shall be decided during design.

#### 10.10.7 Files Format

The file format of all recorded data log files as above shall be submitted along with the tools required for reading and processing the same in batch mode via third party tools.

Naming convention for all different data file types shall be submitted for Engineer's review. Suitable placeholders for time, car ID, equipment ID, trip ID, train ID etc. shall be incorporated.

### 10.11 Wayside Wireless Communication System

#### 10.11.1 General

The contractor shall provide equipment and install the complete system to enable:

- i) Remote access of TCMS data (as defined in ERTS 10.10) on trains present in mainline or Depot(s);
- ii) Remote downloading of TCMS data (as defined in ERTS 10.10) to wayside central server through wireless communication network of signalling/telecom using maintenance notebook computers. The Contractor shall conduct necessary interface with S&T and shall be responsible for complete set up, commissioning and satisfactory working of the system during DLP.

The facilities of remote downloading shall be in addition to the hardwire downloading.

#### 10.11.2 Scope of Supply

##### i) Contractor shall supply: Central server

The data as above shall be downloaded on a central server (to be provided by Rolling stock Contractor), which in turn shall be linked to each Depot, terminal stations, OCC etc. Communication link with server, if required for the purpose, shall be provided by the Employer. However, necessary interfacing devices shall be provided by the Contractor.

##### ii) Wayside Equipment

Within the Depot(s), the Contractor shall install and configure wireless network (in a limited area) for accessing the diagnostic data from the Central Server/Depot Server via maintenance notebook computers. Details shall be discussed during design stage.

All equipment required within Depot(s) and OCC etc. shall be supplied by the Contractor. Any other networking equipment as defined in Appendix-TD shall also be in the scope of RS Contractor. Further details shall be worked out as approved by the Engineer during design stage.



## iii) On-board equipment

Any on-board equipment/access point/switches/router etc., if required, shall be provided by Contractor.

## 10.11.3 Required Features

## i) Download Triggers

The triggers for remote downloading to central server shall be time interval actuated, fault actuated, manual triggered from OCC/BCC and forced downloaded remotely by authorized metro personnel.

## ii) High-Integrity data transfer

Integrity of the data shall not be affected during remote download and in case of any interruption or otherwise the data shall be suitably secured and retrievable.

## iii) Auto Resume of failed downloads

Connection failure during data download shall not cause restart of download from the beginning. Rather, all downloads shall pickup from the point where connection was broken.

## iv) Depot management tools, issue of work orders etc. shall be linked with this software.

## v) The Contractor shall supply the multiuser software(s) required for analysis of the faults and predictions/judgments on likely faults/failures. The specification of the software shall be got approved from the Engineer.

**10.12 Energy Consumption Measurements**

## 10.12.1 General

The Vehicle Control Circuit shall be suitably designed to ensure that Energy Consumption values at specified points are measured, recorded and made easily retrievable. The accuracy and integrity of these measurements shall be specifically ensured as the Employer intends to use the data for getting carbon credits.

The measurements shall be:

- i) made independently at pantograph, converter, auxiliary converter and HVAC levels,
- ii) made separately for traction, coasting and regeneration modes for each train,
- iii) linked with Crew IDs (in non-UTO mode),
- iv) segregable between mainline and depot consumptions,
- v) time stamped every 5 seconds,
- vi) stored in TCMS memory for 60-day period,
- vii) retrievable on VDU as cumulative/integrated values with advanced filtering option.

## 10.12.2 Reporting of Measurements

## i) Display on VDU

The cumulative energy values at pantograph, converter-inverter, auxiliary converter-inverter and HVAC levels with both the components viz. motoring (including coasting) & regeneration, shall be displayed on VDU. It shall also be possible to apply time and trip filters to the energy values.

## ii) Relaying to OCC

Complete energy data shall be transmitted to control centre at assigned times which shall be advised during design. The data shall be stored for one week and shall be downloadable as and when required. Further details including reporting format shall be discussed and finalized during design.

## iii) File Format

The Energy Consumption data shall be exportable to Microsoft Excel in the following format:

Parameter	Time <sub>0</sub>	Time <sub>5</sub>	Time <sub>10</sub>	Time <sub>15</sub>	....
Energy Consumed @ Pantograph (Powering)					
Energy Consumed @ Pantograph (Coasting)					



Energy Consumed @ Pantograph (Braking)					
Energy Regenerated @ Pantograph (Braking)					
Energy Consumed @ CI (Powering)					
Energy Regenerated @ CI (Braking)					
Energy Consumed @ SIV (Powering)					
Energy Consumed @ SIV (Coasting)					
Energy Consumed @ SIV (Braking)					
Energy Consumed @ HVAC (Powering)					
Energy Consumed @ HVAC (Coasting)					
Energy Consumed @ HVAC (Braking)					
Odometer Reading					
State (Powering/Braking/Coasting)					
Crew ID					
Train ID					
Trip Number					
Last Station ID					
Mainline/Depot					
Train Speed					

In above format, the values in blank cells shall only correspond to the recordings made during the 5 second interval between successive timestamps and shall not be accumulated.

10.12.3 Measurement Accuracy

i) Accuracy

All energy measurements shall have accuracy within ±3 % of the measurements made with Standard Wattmeter and Standard Instrument Transformers connected at appropriate test point in the Vehicle Control Circuit. This shall be validated during type tests.

ii) Verification

The Contractor shall be required to submit the detailed arrangement for connecting the standard Instrument Transformers and Standard Wattmeter at the test points for measurement of Energy Consumption for all above defined parameters, during the Type Test. Further details shall be discussed during design stage.

iii) Least Count

The least count for recording data shall be 0.01 kWhr at all levels of measurement.

10.12.4 Analytical Software Tools

The contractor shall also provide suitable analytical tools to screen and analyse the energy data for:

- i) optimization of energy regeneration, coasting,
- ii) right manner/energy saving manner of driving,
- iii) educating train operators,
- iv) identifying the areas where energy can be saved,
- v) calculating efficiency values of transformer, converter inverter, auxiliary converter etc.

10.13 TCMS - OCC Interface

10.13.1 Key Alarms

The contractor shall propose a list of critical/key alarms to be communicated to the OCC in real-time through the signalling network. This list shall include all alarms that are required for maintaining safe train operation.

Any repetitive, hierarchical or cascading type faults shall be suitably masked or combined together to ensure brevity of the information being presented to OCC operator. The key alarms shall also have well defined actionable procedures associated with them as finalised in the OMPD document.



**10.13.2 RSC HMI**

The Rolling Stock Controller (RSC) in OCC shall have facility of full TCMS functionality of any train on his workstation on demand through signalling network. Development of the HMI application in RSC workstation shall be responsibility of Rolling Stock Contractor.

**10.13.3 OCC GUI**

Rolling Stock Contractor shall propose a user-friendly graphical user interface in the form of a conceptual schematic/wireframe that shall include page layouts, arrangement of the GUI's content, interface and navigational elements, and a description of how they work together. This proposal shall be submitted to the Engineer for his approval well in advance and shall be jointly agreed with Signalling Contractor for implementation. The Rolling Stock Contractor shall provide detailed information of the TCMS-OCC interface as implemented in at least two recently executed UTO Projects for reference during design stage. The name of such projects shall be indicated by the Tenderer in the bid.

**10.14 Deliverables**

10.14.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	10.5.4	Necessary hardware and software tools for editing of VDU screens.	In each depot.
2.	10.9.1	Notebook Computers as approved by the Engineer, together with all associated accessories and preinstalled software as per clause 10.9.1	Minimum ten (10) nos.
3.	10.10.7	Tools required for reading and processing of recorded data log files as per clause 10.10.7	One set at each depot.
4.	10.12.4	Analytical Software Tools as per clause 10.12.4	One set at each depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

**11. HEATING, VENTILATION AND AIR-CONDITIONING (HVAC)****11.1 General**

- 11.1.1 The HVAC system for this specification shall consist of only Ventilation and Air-conditioning. The HVAC System shall be installed on each car to provide full control of interior conditions automatically, over the full range of heat loads associated with passengers, miscellaneous electrical equipment, lighting, carbody heat transmission and solar gain as per seasonal changes.
- 11.1.2 HVAC units shall be roof mounted package type. Two identical units per car shall be suitably located to achieve the specified saloon interior conditions.
- 11.1.3 The Contractor shall submit proposals relating to measures to be incorporated to prevent unloading of air-conditioning units under the conditions of stoppage of train at the platforms and inside the tunnels due to high condenser temperature.
- 11.1.4 The units shall continue to operate at maximum capacity at condenser inlet temperatures up to 50°C and derated capacity up to 58°C.
- 11.1.5 The refrigerant used in the air-conditioning system shall be in accordance with the requirements of the Montreal Protocol. Environment-friendly refrigerants, such as R407C, R134a or R410A shall be used.
- 11.1.6 The proposed HVAC system shall be service proven in a rail-borne application, and shall achieve the requisite degree of passenger comfort. It should have minimum weight and low life cycle cost.
- 11.1.7 The estimated weight, power requirements and heat load calculations giving the parameters considered, shall be submitted by the Contractor. The specific measures taken to minimise energy consumption of the HVAC unit shall be detailed in the bid.
- 11.1.8 In order to minimize energy consumption, ventilation control based on CO<sub>2</sub> level measurements and/or load weigh signal shall be used for controlling the performance of the HVAC system. It shall be finalized during detailed design stage with the approval of Engineer.
- 11.1.9 All electrical and electronic components shall comply with the EMC and EMI requirements of IEEE 16, EN 55011 and IEC 61000-4 standards or other equivalent standards. Fire properties of the materials used shall comply with EN 45545.

**11.2 Design Criteria – Cooling and Heating Capacity of the Unit**

- 11.2.1 Passenger comfort conditions shall generally be defined according to ASHRAE 55. The HVAC units shall be designed to achieve car internal conditions for external environment conditions as listed in table 11.1 below:

Table 11.1 External/internal conditions for HVAC design

Weather Conditions	External Conditions	Internal Conditions
Summer	36°C Dry Bulb, 65% RH	25°C Dry Bulb, 60% RH
Monsoon	32°C Dry Bulb, 85% RH	25°C Dry Bulb, 60% RH

## Note:

Provision of humidity control shall be there in the HVAC. Humidity control should be done as per the comfort zone as specified in EN14750-1.

- 11.2.2 The fresh air intake may be taken as 8 m<sup>3</sup>/h/passenger for AW3 condition. The CO<sub>2</sub> level inside the car shall not exceed 2600 PPM at any passenger location when the outside (ambient) CO<sub>2</sub> level is around 450 PPM.
- 11.2.3 Heat gains to be considered for each car shall be calculated according to ASHRAE Handbook Fundamentals and/ or any other acceptable guidelines and shall be mainly as follows:
- Car lighting and electrical equipment heat loads including evaporator fan motors.
  - Passenger heat load in AW3 Condition for DM/T/M car.
  - Carbody heat transmission with an assumed 10 kmph relative exterior velocity.
  - Fresh air (ventilation) heat load should include fresh air intake during the time of opening of doors after every 2 minutes for 30 seconds at the stations. Preferably, the average of actual doors open-close cycle for the train route should be considered
  - A solar load representing direct and diffused radiation, convection and radiation from window



surfaces, and absorbed heat gain from the glazing and carbody structure.

- 11.2.4 The system shall automatically control the temperature throughout the passenger area up to 25°C in cooling.

Temperature sensors for fresh air, return air, supply air, shall be inbuilt in the HVAC unit. All the data shall be logged in TCMS and retrieval on demand from TCMS.

- 11.2.5 Failure of one of the HVAC units on a car shall not adversely affect operation of the other unit. The Contractor shall submit calculations for the inside conditions with one HVAC unit out of operation.

- 11.2.6 The HVAC system shall be designed to achieve the following:

- (i) Air Discharge Velocities: The air velocities inside ducts shall not cause excessive noise and discomfort to passengers in saloon occupancy areas, and shall generally follow internationally accepted practices. The air velocities at specified points in the car, as proposed by contractor and reviewed by Engineer, shall not exceed those set out in EN14750 or any equivalent standard. The supply air discharge velocities at any outlet grille/diffuser shall not exceed 4m/s. The air velocity at any point in the car shall not exceed 0.75 m/s. The air velocity within ducts shall not exceed 8m/s. The air intake velocity at the re-circulation and exhaust grilles shall not exceed 3m/s. Details of the Contractor's proposals shall be submitted.
- (ii) Temperature Distribution: Temperature difference among all points in the same horizontal and vertical planes spread over full car length shall be minimal. It shall conform to EN 14750 or any other standard. The Contractor shall submit proposal for review of the Engineer.
- (iii) Saloon Pressure: The HVAC supply air blower fan shall pressurize the car passenger area. In car stationary car with all doors closed and vestibules blocked condition, the value of interior static pressure shall be between 15 to 40 Pa.

- 11.2.7 In the event of the failure of both HVACs on a car, an emergency ventilation system shall operate automatically to admit fresh air directly into the car to maintain the required oxygen level in accordance with ASHRAE 62. The induction of outside fresh air shall not be less than 10m<sup>3</sup>/h/person, under fully loaded train conditions. The emergency ventilation fans in the saloon shall be fed from the 110V DC supply in the event of non availability of 415V AC supply from single inverter provided in each car.

- 11.2.8 Fresh air should be filtered for human comfort and safety, in accordance with internationally accepted norms. The filter element of G3 grade as per EN 779 or better shall be provided before the fresh air damper and fixed in a metallic frame and shall be easily replaceable from inside the car. Even in the extremely dusty and humid environment prevailing in Mumbai, the cleaning of the filters shall not be required before 5000 kms or 15 days of train run. The filter shall have sufficient effectiveness to ensure that dust deposition in the air duct is bare minimum and cleaning of duct is not required in between major overhauls. Cleaning of the duct shall be simple and contractor shall suggest necessary equipment required for dust removal and sanitization against fungal growth etc. Contactor shall provide minimum two sets of duct cleaning equipments in each deopt. Thermal insulation and sealing of duct shall have zero calorific value. Tapes and other adhesive materials used in ducts shall have minimal calorific value and shall be fire retardant.

The method for cleaning the filters and expected life of filter shall be furnished during detail design stage. Minimum expected life of filters provided shall be 100,000 kms.

Suitable 'Automatic filter cleaning machine' shall be designed and provided by the Contractor in each Depot.

- 11.2.9 Tenderers shall indicate the type of filters proposed to be used by them in the bid. The expected pressure drop across the filter shall be furnished. Details of suitable instrumentation to be used for measurement of pressure drop shall be provided in the bid. Two sets of such measuring instruments shall be supplied by the Contractor in each depot. Each type/ size of filter shall be interchangeable in the fleet.

- 11.2.10 Provision shall be made to shut off the fresh air intake and re-circulate the internal air of the saloon, during an emergency condition, such as fire outside the train causing excessive heat and smoke to be drawn into the vehicle. Operation of such provision shall be made from the OCC in UTO mode of operation and from operative driving console in non UTO mode of operation. The closing time of the fresh air damper shall preferably be less than 10 seconds from the receipt of smoke signal to avoid ingress of large quantity of smoke inside the car. Location of the smoke detectors and the

logic for smoke signal shall be designed in such a way that possibility of false alarm is avoided. Full details of the system proposed shall be given. Provision shall be available to bypass the smoke detectors though TCMS.

11.2.11 Deleted.

11.2.12 The HVAC units fed by one Auxiliary Power Supply Equipment shall have staggered starting in a sequence to reduce the inrush current load due to simultaneous starting of air-con motors. This may be achieved through Programmable Logical Controller of the units and TCMS.

11.2.13 The HVAC unit shall have optimized cooling capacity control for quickly reaching and maintaining the comfort conditions with low power consumption, depending on ambient conditions and the number of commuters inside the car.

11.2.14 Employer expects that an energy efficient system comparable with the best available in the market shall be provided. Good energy efficiency shall be achieved in cooling and de-humidification operations of the HVAC. Contractor shall furnish Energy Efficiency Ratio (EER) for the offered system. In cooling mode, the Coefficient of Performance (COP) of HVAC shall be at least 2.5 in summer ambient conditions under all loading conditions from AW0 to AW3 which may be achieved by utilizing variable frequency control (if required) of compressors or any other control mechanism. The COP shall be validated as per IS8148, ASHRAE 37 or any other relevant standard, as agreed by the Engineer. The Contractor shall submit the record of proven system already functional in any metros with the specified COP. The Contractor shall furnish expected power consumption of the HVACs per car for peak Summer, Monsoon and Winter ambient conditions for AW0, AW1, AW2 and AW3 passenger loads.

11.2.15 In the event of failure of an auxiliary power supply equipment on one 3 car unit in 6 car train, the remaining 3 car unit auxiliary power supply equipment must be capable of supplying all auxiliary power to HVAC of complete 6-car train. Under such Condition, all HVAC units shall work at 50% of the rated capacity.

11.2.16 Supply air blower fan can have two speeds to give energy saving at lower passenger loads. At the lower blower fan speeds, the supply air flow rate shall not be less than 3000 m<sup>3</sup>/h each unit and the car interior pressure not less than 10 Pa.

### 11.3 Heating System

11.3.1 Deleted.

11.3.2 The heater shall be installed, if required in the evaporator unit, downstream of the evaporator coils, to condition the fresh air intake and for reheating to control humidity as mentioned in clause 11.2.1 above.

11.3.3 The control circuitry shall not allow the heaters to be powered unless the evaporator blowers are operating. Heater element over temperature protection shall be provided. Self-resetting thermostats shall be installed adjacent to the heaters to open the contactors when excessive temperatures are detected. A positive interlock shall be provided to open heater contactors in the event of failure of the Auxiliary Power Supply Equipment.

### 11.4 Roof Mounted Package Units

11.4.1 Two package type HVAC units, with all equipment required for satisfactory functioning of the system, shall be provided on each car.

11.4.2 Each unit shall be arranged on an integral stainless steel (SS 316L) frame, removable from the car as a single complete module. The integral frame housing of the unit shall be constructed in such a manner that any corrosion in service on any account is avoided and the box shall last for the lifetime of the HVAC unit without needing any attention. HVAC frame/cover shall be suitable for free movement of maintenance personnel without any consequential damage to covers/equipment. The finish of the frame shall match and will be in harmony with the car body finish.

11.4.3 The complete operation to remove and replace a unit should be simple. The Contractor shall declare the weight of the complete unit. Details of specialized mechanical handling equipment shall be provided.

All electrical connections shall be fitted with quick disconnection fittings, which would be at easily accessible locations.

11.4.4 The frame housing shall be designed and constructed so that access for inspection and routine maintenance is from roof hatches, hinged at one side, secured by captive bolts on the other, and



provided with stops to retain them securely in the lifted position when opened.

- 11.4.5 The carbody roof walls for accommodating the overhead air-conditioning units shall be a compartment in the car roof structure. Each wall shall provide a continuous watertight and weatherproof area complete with adequate water drains to prevent rain, condensate or washing water leakage into the car.
- 11.4.6 Fresh and return air shall be filtered before being passed over the evaporator coil. It shall be possible to remove and replace air filters from inside the cars conveniently without the need for removal of any cable connection.
- 11.4.7 Air-conditioned unit shall have noise less compressors & condenser fans. Condenser fan assembly and evaporator motor-blower assembly shall be balanced in two planes, in-situ, as defined in ANSI/AMCA 204, and the residual unbalance should limit vibrations at motor end bells within 0.025 mm peak-to-peak displacement, or 2.3 mm/s RMS velocity, in any direction. However, any other balancing method may be proposed by the Contractor with the approval of Engineer. This shall be a type test on prototype unit.
- 11.4.8 Fresh air velocity at the HVAC outside grille face shall not be more than 2 m/s to prevent rain water from entering the HVAC along with fresh air. Similarly, mixed air velocity at the evaporator coils shall not be more than 2 m/s to prevent condensate water travelling to heating elements and supply air plenum/ducts.
- 11.4.9 The design shall ensure easy cleaning of the drains, evaporator coils, and condenser coils without need for lifting of HVAC unit from the car roof. Filter replacement, data downloading by PTU, electrical connection cubicle, control panel cubicle etc. shall be easily accessible from inside of saloon to the maintenance personnel, but not to the passengers.

#### 11.5 Air Ducts and Diffusers

- 11.5.1 Conditioned air from each unit shall be directly introduced into a duct running the full length of the car and be discharged into the car through ceiling outlets.
- 11.5.2 Adequate sized duct from adjacent AC to the cab shall be routed to the driving cab, control cabinets and driving console. Air turbulators shall be provided in the driving console, signaling cubicles and electrical cabinets to achieve uniform cooling.
- 11.5.3 The supply air duct shall be constructed from stainless steel or anodised aluminum. It shall be diagonally split for each HVAC unit to feeds one side of the car, so that even in case of failure of one HVAC, the other working HVAC will be able to cool the saloon passenger area uniformly. The duct shall be fully lagged with non-combustible insulation material to prevent the formation of condensation. The Duct shall be suitably designed to ensure that there is no leakage of supply air between the two halves of the duct. The metallic partition shall be preferred for this purpose. The design shall ensure that in the event of failure of cab end HVAC, the bleed of cool air is always available in the cab. The Contractor shall take into consideration the requirement of maintenance access for duct cleaning as and when required.
- 11.5.4 Two rows of air diffusers shall be mounted on each side of ceiling panel, aesthetically blending well with the car interior design. It shall be possible to adjust the air quantity coming out from the diffusers during testing and commissioning, so that uniform distribution of air supply is achieved in the passenger area (to the maximum extent possible). The details of the diffusers shall be submitted.
- 11.5.5 The design of duct shall take account of the possible need to provide a recess in the roofs of cars, to accommodate the support for the pantograph base arrangement.
- 11.5.6 Exhaust air path shall be provided in the car. If needed, exhaust air fan and/or motor controllable exhaust dampers may be provided (Refer Chapter 4).
- 11.5.7 Computational Fluid Dynamic (CFD) analysis tools should be used to optimize the air distribution within the car. This study should be undertaken to confirm that all the design air velocity and airflow rate values are being achieved and shall be validated during the design stage.

The completion and submission of CFD analysis shall be a pre-requisite for issuance of NOC for Pre-Final design

#### 11.6 HVAC Unit Compressor

- 11.6.1 The Contractor shall provide hermetic scroll compressors proven for sufficiently long time in Metro service. Scroll compressor shall be suitable for continuous operation at high ambient temperatures of up to 50°C and limited operation at 58°C ambient. Full details of the compressor and its experience in Metro train application, particularly in high temperature, dusty and high humid



environment shall be furnished. Unloading of compressor shall be linked with the HP setting.

#### 11.7 Condenser and Evaporator Coil

- 11.7.1 The condenser and evaporator coils shall be of copper having copper fins. Condenser fins spacing shall be no closer than 3 mm and evaporator fins shall be 2.5 mm or more apart, in order to prevent dirt/dust build up. Thickness of fins shall be minimum 0.2 mm. The coil assembly shall be mounted in a stainless steel / copper alloy frame. Cleaning of condenser and evaporator coils should not be required earlier than 6 months after putting the train into revenue service. The proposed frequency of cleaning of coils in Mumbai climate shall be furnished.
- 11.7.2 The condenser and evaporator fan motor shall work on 415V, 3 phase, 50Hz supply. However, in case of auxiliary supply failure, the evaporator fan motor shall be fed from the inverter. Dual speed condenser fan motor may be used. The fan motors shall have IP 56 protection as per IEC. There shall be separate MCBs for condenser fan and supply air fan.
- 11.7.3 A condensate drain stainless steel pan shall be provided beneath the evaporator coil. Baffles shall be provided in the pan to prevent spillage. Adequate big size drain pipe shall be provided for drainage of condensate from the drip tray to the rain gutters. Suitable means shall be incorporated for cleaning of the water drainage system.

The design of rain gutter shall ensure smooth passage of water drainage and muck.

- 11.7.4 Quality of HVAC copper tubing and joints shall be of a very high order so as to minimize chances of refrigerant leakage. 'U' or 'L' shaped pipes should be used to connect condenser/evaporator coils to headers. Long overhangs should be avoided. All brazing joints of the condenser and evaporator coils and headers shall be lap joints. The brazed joints may have to be provided with suitable coating to insulate them from environment pollution. Extra coating at the header portion shall be provided. Leakage testing of high sensitivity (should be able to detect 1 gm/year leakage) shall be done on condensers and evaporators after making them but before application of extra coating and before assembling on the HVAC unit.
- 11.7.5 Condenser coil protection of exposed headers and return bends should be accomplished by ancillary guards or shields to the coil, or to the surrounding unit structure. All protection plates should be easily removable for coil cleaning and to gain access to the tubes brazed connections for repairs.

#### 11.8 Piping

- 11.8.1 The refrigerant piping shall be of seamless copper tubing as per ASTM B280 or B743, with suitable non-ferrous fittings. All fittings should confirm to ANSI B31.5 and the connections between the piping and equipment shall be made using capillary fittings brazed lap joints. Fittings and joints should be accessible for leak test. There may be relative movement between the terminals of the compressor and the condenser and evaporator coils resulting from vibrations. The pipe layout shall take this aspect into consideration. Long unsupported overhangs should be avoided. 'U' or 'L' shaped pipes should be used to connect two assemblies.
- 11.8.2 In order to provided adequate strength against shocks and vibrations, all tubing joints should be brazed with an alloy containing 15% silver for copper-to-copper joints and minimum 40% silver for dissimilar metal joints.
- 11.8.3 Proper refrigerant leakage testing shall be done once all the copper tubing brazing is complete, just before charging of the refrigerant. No part of the assembly under test shall show signs of refrigerant leakage greater than 3 g/year under normal working pressure and shall be tested using measuring instrument of 1 gm/year least count.

#### 11.9 Electrical control cubicle

- 11.9.1 Electrical switchgear and control equipment for the system shall be located in a sealed cubicle, which shall be an integral part of the HVAC package unit. The electric switches, contactors and relays etc. should be proven in Metro train application. The cables shall be halogen free compliant to EN 45545 Part 1 to 7 in respect of flammability, smoke emission and toxicity requirements.

#### 11.10 Control Equipment

- 11.10.1 Each HVAC unit shall be associated with its microprocessor control panel which shall be easily accessible from within the car. The micro-processor based system, proven in railway service environment shall be provided with loading, scheduling, diagnostic and operational data interfaced with TCMS.
- 11.10.2 The microprocessor shall have extendable memory permitting logging of faults and system events in its memory for sufficiently long durations. The microprocessor shall have suitable interface with



TCMS for data communication and display. Suitable communication shall be provided to permit logged events to be downloaded to a laptop computer.

The units shall be capable of being controlled from the OCC in UTO mode of operation and from driving console in non UTO mode of operation. Facilities for remotely cutting-out and resetting of a faulty air-conditioning unit should be provided in OCC in UTO mode of operation and in the train operator's driving console in non UTO mode of operation.

High Pressure (HP) and Low Pressure (LP) values shall be monitored by TCMS.

11.10.3 Control of passenger area comfort conditions shall be done through Solid State type temperature and humidity sensors having no moving parts. For this, following minimum number of sensors shall be provided:

- (i) One fresh air intake temperature sensor in each HVAC unit.
- (ii) One each return air inlet temperature and humidity sensors in each HVAC unit.
- (iii) Temperatures recorded by the HVACs return air temperature sensors and the humidity values recorded by the HVAC's return air humidity sensors will be the feedback to the HVAC control system for taking corrective actions for maintaining the car interior passengers comfort conditions.
- (iv) Temperature sensor in the supply duct to prevent supply air from overheating.
- (v) Heat detectors/temperature sensors shall be used and integrated to TCMS/Fire Detection Control Unit for real time monitoring of all connections/points of the HVAC cables in vicinity of return air duct.

#### 11.11 Emergency Inverter

11.11.1 An Inverter of adequate capacity shall be provided in each car to supply 3 phase AC power from 110 Volt DC battery to power the ventilator fan motors of the car during emergency mode, when cooling is off and for supplying emergency fresh air. Inverter shall be IGBT based and tested in accordance with IEC 61287. The current rating of IGBT shall be such that the junction temperature has a minimum margin of 10°C in the worst loading conditions. The inverter shall be located in inside the HVAC unit.

#### 11.12 Operator's Cab Air-conditioning

11.12.1 Separate cab AC unit is not envisaged. The cab, driving console and electrical cabinet in the cab shall be conditioned from the saloon HVAC. The ducts shall be suitably designed. Facility shall be available for independent air control in the cab. Separate air supply fan motor shall be provided for controlling the air supply in the cab. The temperature inside the driving console and cab shall be same as in the saloon i.e. 25° C under stipulated conditions.

#### 11.13 Earth Fault Protection

In case of grounding in any HVAC unit, it shall be possible to isolate the defective HVAC unit without affecting the static inverter operation. Contractor shall submit the proposal for Engineer's review during design stage.

#### 11.14 Deliverables

11.14.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	11.2.8	Automatic filter cleaning machine	In each depot.
2.	11.2.9	Suitable instrumentation for measurement of the expected pressure drop across the filter.	Two sets in each depot.

#### Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

**12. ELECTRICAL AND CONTROL EQUIPMENT****12.1 General**

12.1.1 On-train electrical equipment and control circuits, other than those for the propulsion system, shall use one or more of the following power sources:

- (i) 415V AC, 50 Hz, 3 $\phi$ , 3 wire
- (ii) 230V AC, 50Hz, 1 $\phi$
- (iii) 110V DC
- (iv) 24 V DC.

12.1.2 AC single phase levels at the load end shall be within  $230 \pm 6\%$  V and  $50 \pm 3\%$  Hz.

**12.2 Train Control and Operational Principles****12.2.1 Modes of Operation****(A) General**

The train shall employ following modes of operation:

- (a) Unattended Train Operation (UTO) Mode: The train shall be operated without train operator under GoA4 mode. OCC will send a command to ATC system onboard to operate the train so as to align train doors with the PSDs.
- (b) Restricted Manual (RM) Mode: manual operation in forward/reverse direction at maximum specified speed (to be specified) with over speed protection from onboard ATP. This mode should be used during train shunting in the depot in the area where UTO is not operational and recovery operations during train failures online.
- (c) Standby Mode: Initialized train with minimum control functions with traction control shall be in-operative and brake shall be applied during this mode.
- (d) Coded Manual (CM) Mode: Train to be manually operated in forward direction up to a maximum speed permitted by onboard ATP. Door controls to be operated by the Train Operator.
- (e) Auto Mode (AM): Automatic driving in forward direction by Signalling systems GoA2/GoA3.
- (f) Cutout Mode: Full manual operation during cutout of signalling equipment under Employer's operational procedures. Maximum speed to be limited by a preset limit controlled by TCMS.

**(B) Unattended Train Operation (UTO)**

- a) During UTO mode, signalling system shall control the train with mode selector at UTO position and the UTO engagement push button in ON position activated from the cab or from trackside/OCC.
- b) The Contractor shall list down all possible operational scenarios while designing the interface with Signaling & OCC (Telecom), the Contractor shall thoroughly examine all possible operating scenarios of line 2 and 7 including those which may arise out of interface with designated Contractors. The Contractor shall prepare a detail document on possible implications of different failures and incidences that may occur during operations and responses to & from signalling and/or OCC. During such analysis the Contractor shall ensure that complete information has been transmitted to enable signalling /OCC to work correctly, safely & reliably as per interface design.
- c) The status of relevant equipment, MCBs etc. shall be relayed to Signalling/OCC and shall have remote control facility to reset the MCBs as decided by the Engineer during design stage.
- d) It shall be possible to initialize the train from OCC/DCC when UTO command is being received by the train. Within depot premises, UTO mode shall be functional within specified area and it shall be possible to launch the train after self checks including door operation and Brake dynamic test and preparatory works through OCC/DCC command. In case of failure of



- the train to pass its self-test, OCC/DCC shall get the message and train shall be operable by Train Operator.
- e) Similarly, train shut down shall be implementable from OCC/DCC and any failure shall be reported back.
  - f) Built in safety measures, as applicable, shall be implemented during UTO initiation /failures.
  - g) Signalling system shall control door operation with in-built safety provisions which shall be documented by the Contractor. In case of any defect in door operation, OCC shall be informed with door identity.
  - h) The operation of the passenger train doors shall be under the control of signaling system. If the door system detects conflicting signals, the door status shall remain unchanged and a message shall be sent to the OCC. In the event that the door is unable to close after the predetermined number of times of re-close, a message shall be transmitted to the OCC giving the identity of the train and suitable message shall be broadcasted in the train.
  - i) Interface of PA & PIS system with signalling system shall include display & route update, broadcast of messages etc. Failure of signalling system shall be recorded and fall back mode shall be resorted to.  
Video analytic software shall detect any abnormal condition in the car which can be recorded as emergency case.  
Contractor shall prepare detail functional/ operation document. Similar document shall be prepared for interface with Telecommunication and other sub systems.
  - j) In case of short stop/over-run, OCC shall be able to issue jog/creep command for signalling system to send traction/brake command.
  - k) OCC shall get details of the track conditions such as rail fractures, running edge defects, rail head surface defects, missing fasteners etc. through a suitably designed Digital Line Scan Camera with automatic real time detection and warning up to 90 kmph of train speed. Such camera shall be installed on both DM cars of 4 no. of trains. Trains on which the equipment shall be installed shall be decided by the Engineer.

Similarly, a Digital Line Scan Camera with automatic real time detection and warning shall also be installed on leading (DM) cars of 4 no. of trains at appropriate place for monitoring of overhead catenary conditions and interface between OHE and pantograph, up to 90kmph of train speed.

Also, provision for a video camera on roof of each T-car at appropriate place in all trains with a view to continuously monitor and record the pantograph and OHE interaction shall be ensured. Purpose of these cameras shall be to analyse the events post failures of pantograph or OHE including panto pan entanglements or for monitoring by Train Operator or Maintenance Personnel while train is in running condition. On demand, the feed from each of these cameras (on selection) including historic data shall be available on TCMS in ATP/ATO operation and in OCC under UTO operation. Sufficient storage capacity to record these data for at least 7 days shall be ensured.

- l) OCC shall be able to selectively operate/isolate pantograph(s).

12.2.2 The control and operation shall be based on the optimized combination of the following principles:

- (i) Maximum safety,
- (ii) Maximum reliability and availability,
- (iii) Operator convenience and ergonomic design,
- (iv) Adequate redundancy,
- (v) Energy efficiency,
- (vi) Maintenance support.

- 12.2.3 The control logic shall ensure that the vital train control functions (such as couplers, door system, brakes, propulsion power removal, PEA etc.) are executed using conventional relay control and dedicated hardwired train line signals. All vital circuits including above shall be double wire, double break. The identified safety critical signals shall be carried using redundant train line pairs.
- 12.2.4 Warnings and indications that are necessary for safe operation of train shall be indicated by means of power LED lamps and shall also use hardwire system.
- 12.2.5 TCMS link shall be used to execute non-vital commands and controls of the train.
- 12.2.6 In addition, TCMS link shall be used for the identified non-vital control functions through VDU interface. TCMS link shall also be designed to provide back-up signals of certain identified vital commands to be finalized during design stage.
- 12.2.7 The Contractor shall develop overall control logic for review of the Engineer. The proposed equipment shall be service proven and reliable.
- 12.2.8 The Emergency Brake Push button (mushroom type) operation shall actuate emergency brakes without opening Line circuit breaker and lowering of the pantograph. In order to ensure that train is not stalled in the section due to defect in emergency brake application circuit, provision shall be made to by-pass the brake loop and drive the train with limited speed in either direction. Separate push button (protected against inadvertent operation) for opening circuit breakers shall be provided on driver's desk.
- 12.2.9 Provision shall be made to switch off line circuit breakers if required during emergency.
- 12.2.10 It shall be possible to independently move a single unit (with DM car) within Depot. The required switches shall be protected against any inadvertent operation and shall be placed in a cubicle near gangway. Final command for decoupling shall be given through the cab only. The switch positions shall be recorded with time stamp.
- 12.2.11 Saloon light status shall be made available in HMI.
- 12.2.12 A minimum provision of spare 10% relays, contactors, MCBs terminal blocks and contacts shall be made in the respective circuits and at their locations. These shall be duly wired up to terminal blocks. Sufficient margin may be taken by Contractor during design so that above criteria is met at the end of DLP period.
- 12.2.13 All such critical contacts which can lead to failure shall be duplicated to ensure the full redundancy i.e. double wire, double brake, paralleling of contacts etc. The Contractor shall specifically elaborate compliance to this clause during design. In case any such contacts are identified during revenue period by the Engineer, the same shall be rectified by the Contractor at no extra cost.
- 12.2.14 Any isolation / failure shall be manageable from the working cab so that the train is not held up in main line and corrective action is taken with minimum loss of time.

### 12.3 Trainline Electrical Connections

- 12.3.1 Electrical contact blocks, mounted on the semi-permanent coupler shall be provided. When the automatic couplers are mechanically coupled, automatic pneumatic coupling shall be affected between the mating couplers. Electrical connectors for the semi-permanent couplers shall be mechanically secured together. All couplers shall have provision of suitable plug in covers to be provided when not connected in the train formation.
- 12.3.2 The Contractor shall submit details for inter-car and inter-unit connections to meet the necessary train operation requirement. Adequate number of spare connection pins (at least 10% of each type) shall also be provided at the end of DLP. Wiring from spare pins shall be brought till the nearest cubicle in the car/cab. Contractor shall keep an extra margin of 5% so that the same may be utilized by them during DLP for carrying out hardware modifications. The Contractor shall keep sufficient margin of additional spare connection pins at design stage so that, by the end of DLP, still 5% spare is available for carrying out any hardware modification in future.

As a minimum, the following functions shall require train line controlled by 110 V DC control supply:

- (i) Brake command and emergency brake,
- (ii) Propulsion Enabling Circuits (Direction control mode etc.),
- (iii) Door Enabling (Each side),
- (iv) Safety related auxiliary commands,
- (v) Train line Integrity,



- (vi) Air gauge,
- (vii) Coupler Control,
- (viii) General fault indication for TCMS,
- (ix) Parking Brake Control,
- (x) Master Controller,
- (xi) CCTV & PA & PIS,
- (xii) Additional Train line circuits as required for train brake signaling and communication systems. Information shall be supplied and finalized at design stage.

- 12.3.3 The free end of the cabling from the electrical connector shall be terminated in a multi-pin plug (s) with compatible socket(s) at the interface with the car wiring.
- 12.3.4 All exposed cables at the exterior including the inter car jumper cables, if any shall have suitable mechanical protection.
- 12.3.5 At least 10 no. of spare train lines shall be available at the end of DLP. Suitable number of spares shall be ensured by the Contractor during design.
- 12.3.6 Design of panels for push buttons, rotary switches, MCBs & relays etc. shall be such that future addition of these components is easily possible without any modification to the main panel. Each panel shall have at least one push button/rotary switch as spare duly mounted and wired up to the main electrical cubicle terminal block. Critical circuits which have possibility of having possibility of other circuit elements getting non functional thereby leading to train detention on line, shall have independent MCBs.
- 12.3.7 Relays shall have provision to add-on auxiliary contact blocks when mounted on the train. Contractor shall have provision to provide and mount the add-on blocks if required by the Engineer during the DLP period.

#### 12.4 Control equipment

- 12.4.1 The control equipment relays, switches connectors, terminal blocks, earth-pads, cable gland, connector plugs and receptacle, push buttons, switches, safety cut-out switches, line voltage indicators, relays, magnetic contactors, DC/DC converters and cam switches etc. provided in the panels/boxes shall be proven for Rolling Stock application. A list of all such components and manufacturer's technical catalogues for the same shall be submitted in design phase, and included in O&M Manual.
- 12.4.2 It is preferable that types of the identified control equipment are limited to a minimum.
- 12.4.3 Control equipment Panels inside the car/cab shall be with IP53 or better protection level. Main and auxiliary contacts of contactors and relays shall be with adequate protection against dust ingress. The distribution panels in the underframe shall be with IP 65 protection. The IP of display & indicators shall generally be not less than IP 53.
- 12.4.4 The panels with components shall be tested in accordance with IEC-60077, IEC-61373 and IEC 60529.
- 12.4.5 The panels/boxes shall be made of Aluminum / Stainless steel. All panels and boxes including the covers shall be individually earthed.
- 12.4.6 Wherever considered necessary by the Contractor and the Engineer, contacts shall be duplicated to provide redundancy. Inter-vehicular control couplers and data transmission pairs shall be duplicated to ensure reliability of operation.
- 12.4.7 Contractor shall use Mors Smitt BK-400 or equivalent relays for system/function as mentioned hereunder and any other safety function. Contractor shall submit complete details for review of engineer during design stage.

S.No.	System/Function
1.	Head Control/Cab Active
2.	Tail Control/Rear Cab Active
3.	Door system
4.	Zero Velocity

12.4.8 Safety relays (sealed type) shall be used for all vital commands and circuits. Safety relays shall be those relays which can lead to immobilization of the train. Contractor shall ensure that the failure of safety relays shall be on fail safe side to avoid unsafe conditions.

**12.4.9 (i) Features of Relays and Sockets:**

- All relays must have a transparent cover to ensure visual inspection from outside the relays. All relays must be equipped with a LED to visual indicate the coil activation.
- All relays must be mounted in a socket ensuring easy swapping of relays in the installation without the use of any tools. The socket or relays must be equipped with a retaining clip or snap lock ensuring proper mechanical installation under IEC 61373 conditions.
- The relay sockets shall be suitable for panel, rail or front mounting style. The wire connection shall be twin connection per relays pin with spring terminal.

**(ii) Relay Testing Kit:**

- Contractor shall provide two no. of portable Relay Testing Kit in each Depot to quickly identify the relay condition. It shall be capable of testing instantaneous and timer relays on correct functionality (no jammed contacts), minimum operating voltage, contact quality, operating time and delay time.
- The relay testing kit shall be suitable for various types of relays used in the Rolling Stock and shall also be able to electrically clean relays contacts.

**(iii) Extension of Relay base:**

Contractor shall provide two no. of tools in each Depot for extension of each type relay base (i.e. duplicating all the relay pins) for unattended system monitoring (measurement of current and voltage) without affecting the train electrical system in any way.

The tool for extension of relay base of all type of relays shall be able to fit in tightly packed relay panels and small cabinets. It shall operate unattended once fitted in electrical cabinets, enabling normal passenger operating service. The tool kit consists of:

- A Test Block -which shall be put between existing relay socket and the plug-in relay.
- Break-Out Box – All the relay pins from the Test Block shall be wired to this box for the duplication of relay pins.
- Data Monitoring and Logging Device –which shall be connected to Break-Out Box for the monitoring of relay pins (i.e. measurement of voltage, current etc.).

**(iv) Dummy Relay (test switch):**

The Contractor shall provide a dummy relay (test switch) for each relay type in each depot for testing, commissioning and fault finding purpose. The Plug-in test switch shall be able to simulate relay operation in an electrical installation, with latch able manual operation and voltage presence indicator.

12.4.10 Contractor to make provision for paralleling of contacts of approximately 20 different relays, which shall be finalized and approved by the Engineer during the Pre-Final Design Review.

12.4.11 Same relay's contact shall not be used in redundant loops/circuits.

12.4.12 Interlocks and auxiliary contacts connected with important protective, operation, control, auxiliary and safety circuits will be housed in dust proof enclosures either by providing the complete equipment in dust-proof cabinets and/or pressuring the cabinets or by covering the contacts only by dust-proof covers of a satisfactory design in accordance with IEC 60529.

12.4.13 The voltage range of all relays and contactors will be 77 to 138 V DC (110V DC –30%, +25%, in accordance with IEC requirements). These devices will work within this voltage range properly under their rated temperatures and contact pressures. The contact pressure will be adequate to ensure satisfactory operation under most severe working conditions.



- 12.4.14 All control equipment like relay, contactors and switches shall be installed such that they are fully accessible for inspection (from the front), repairing in situ or removal and replacement. All relay and contactors shall provide a clear visible indication of the state of the device.
- 12.4.15 The safety relay shall be rated to achieve the life expectancy for anticipated number of operations in 35 years. The relevant calculations shall be submitted to the Engineer during design stage. The other relays and contactors shall be rated to achieve a life expectancy of minimum 15 years before replacement of wear parts, adjustment or testing. The contact rating shall account for the anticipated number of operations over 15 years, system voltage, power factor or time constant of the load, switching current, nature of load separation, any use of contact in series, mounting orientation.
- 12.4.16 All push buttons and indicators shall be uniform in style and shall be arranged, size, label properly as far as possible all push buttons and indicator lamps shall be of the same manufacturer. All push button shall be of push to light type.
- 12.4.17 All push buttons switches and combination push buttons / indication shall have silver plated terminals and contacts. The contact shall be so designed that they will not weld in service when used within their rating and will not bounce closed while the car is in motion.
- 12.4.18 Contacts of critical push buttons shall be duplicated for improving reliability. Details shall be decided during design stage.
- 12.4.19 All redundant loops/circuits shall be fed from separate MCB and shall have separate supply.
- 12.4.20 All critical loops/circuits (TCMS, EB, motoring braking train lines etc) including redundant loops shall be monitored in TCMS and failure message shall be generated in case of its failure.
- 12.4.21 All critical relays, contacts, MCBs, pushbutton, Input output units, switches etc shall be monitored in TCMS. Contractor shall submit details to review of engineer during design stage.
- 12.4.22 Redundant control cables for TCMS, EB etc shall be made to pass through separate connectors.
- 12.4.23 All contact's operations shall be monitored using its auxiliary contacts. Contractor shall ensure adequate spare auxiliary contact.

## 12.5 Wires and Cables

- 12.5.1 All wires and cables shall be adequately protected for the maximum design and fault currents, and designed for minimum voltage drop.
- 12.5.2 The insulation of all wires and cables including those used within equipment / subsystem shall be halogen-free flame- retardant and formulated to minimise generation of smoke, noxious emissions and corrosive fumes, in the case of overheating or fire in compliance with EN 45545 (Category 4-A, Hazard level HL3) latest edition. All Cables shall comply NF F 63-808 (for low voltages), and NF F 63-826 (for high voltages) or other international standards like EN 50264(Part 1 to 3) and EN 50306(Part 1 to 4) as approved by the Engineer.
- 12.5.3 Fire resistant cables shall be proposed for circuits, which should survive for long periods during fire, as per applicable international standards. As a minimum, the cables and wires for Public Address System, emergency lighting, door opening and warning systems shall be fire resistant in compliant to EN 50200.
- 12.5.4 The system adapted to rate cable shall be fully specified for review. All de-rating factors shall be applied, together with the maximum permissible conductor temperature for the particular insulation type. In no case shall the conductor continuous temperature exceed 90°C. The maximum short circuit temperature shall not exceed 250°C. The cable insulation shall be capable of withstanding these temperatures.
- 12.5.5 The minimum cross sectional area of control cables for connections between equipment shall preferably be 1.5 mm<sup>2</sup>. Any deviation from this requirement, in exceptional cases, will be subject to review by Engineer in design stage.
- 12.5.6 The proposed cables shall be proven on metro Rolling Stock. The Contractor shall submit the voltage grade, size and type of cable for different applications along with the proposed specification for the cables for review by the Engineer.
- 12.5.7 Complete cabling layout shall be designed to ensure that they are easily accessible without major



dismantling of the train/equipment so that it is possible to add-on any additional cable(s), if required to be incorporated in respective circuit. Contractor shall establish/validate the compliance during design and mock up review.

## 12.6 Indication Circuit

12.6.1 All hardware indications shall be with LED type. Failure of a single LED shall not cause incorrect indication. Individual cars shall have local indication of the operating status of the equipment, being remotely indicated in the VDU display, through TCMS.

12.6.2 Indication on DM Car

Backup LED indication for critical function shall also be provided in the DM Car. In addition to VDU display, the indications provided shall be for train and car level. All indications shall be provided either on the train operator's console or on the panel behind and adjacent to the driving position. The Contractor shall furnish a list of indicators including function, control and display format for review.

12.6.3 Train Lines for Indication Circuit

The Contractor shall submit proposal for train lines utilised for the indication circuits.

## 12.7 Circuit Protection and Earthing System

12.7.1 All electrical circuits shall be protected by fast acting, 10kA fault current rated MCB's. The Contractor shall propose a protection scheme for review. The Contractor shall submit a detailed protection scheme including calculations to demonstrate proper segregation and discrimination between the cables, fuses and the traction substation circuit breakers. Calculations shall be submitted to verify proper discrimination between different levels of the protection system.

12.7.2 All equipment shall be adequately earthed, insulated, screened or enclosed and provided with essential interlocks and keys as may be appropriate to ensure the protection of the equipment and safety of those concerned with its operation and maintenance.

In case of any loose connection which may result into overheating of incoming wires then in such scenario protection shall be so designed that it shall be able to isolate the equipment without any major fire or overheating of the sub system or its cases. This protection scheme shall be independent of the overload protection & shall be capable of acting much before the load current reaches to its set tripping level.

12.7.3 All equipment on the vehicles, except the battery boxes shall be safety grounded to the carbody structure. The safety grounding shall be distinct from power return grounding. Safety grounding points shall be of tinned copper, clean, free from paint, and of a sufficient area to ensure proper electrical contact for the grounding cable fasteners. Untinned bronze grounding points and austenitic grade stainless steel grounding points are also considered acceptable.

12.7.4 The area of any weld joining the grounding pad to a surface shall be at least equal to the cross-sectional area of the grounding cable. Grounding points will have either a tapped hole or, preferably, a clearance hole (with access to both sides) suitably sized for the lug attachment fasteners. Minimum grounding cable size will be 6mm<sup>2</sup>.

12.7.5 An earth fault detection system shall be proposed by the Contractor for review. Protective devices shall also prevent fires resulting from short circuits, or other electrical defects.

12.7.6 The Earth Concept shall such that requirement in audio frequencies used in signaling track circuits is met.

12.7.7 All electrical circuits shall be fully insulated from the superstructure on both the positive and negative sides and the super-structure shall not be used as any portion of an earth return circuit.

12.7.8 Earth fault protection shall be provided on control, auxiliary and traction power circuits, so that it shall be possible to continue operation for a limited period even where there is one earth fault on the circuit. For this purpose, the earthing of the circuits may be provided through the coils of earth fault detection relays and the supply battery.

12.7.9 All electrical and electronic equipment shall be protected against surge or transient voltages caused by switching (internal or external to the Rolling Stock), lightning discharges and line voltage disturbances by the provision of suitable filters or surge suppressors.

## 12.8 Lighting System

12.8.1 Exterior Lighting



- (i) Exterior lights lens assemblies shall be sufficiently robust to resist the impacts of flying ballast.
- (ii) The IP protection shall be IP65, when fitted on the carbody.
- (iii) Deleted.
- (iv) Individual power LED clusters used as exterior lights shall be able to be replaced easily from track level. Replacement of individual cluster shall be possible in depot without disturbing the functioning of the light. In case, the change of cluster requires readjustment of complete light or component, facility for the same shall be provided in each depot.
- (v) Access for cleaning and the replacement and adjustment shall be possible.
- (vi) All LEDs shall conform to the minimum requirements as specified in ERTS 12.9 and its sub-clauses.
- (vii) Complete lighting system(s), their components shall generally conform to relevant ENs/IECs applicable for railway applications and shall be type tested.

#### 12.8.2 Head and Tail Lights

- (i) Power LED based Head- and tail-lights in watertight sealed, vermin-and-insect proof integrated housings placed at approximately 3m centres and 1.5m above top of rail datum, beneath the windscreens. The units shall be "handed", left and right, so that the taillights are outboard of the headlights.

The two power LED based white light, with provision for dipper shall be mounted at the front of the driving end of the DM Car, to provide even illumination of the tunnel bore (if available), track bed and track side signal posts. It shall be possible to read the number plates provided on the OCS masts and other boards like pantograph lower / raised boards. The illumination level of the head light shall be as per the international norms. Replacement of individual cluster shall be possible in depot without disturbing the functioning of the light. In case, the change of cluster requires readjustment of complete light or component, facility for the same shall be provided in each depot.

- (ii) Each beam shall be separately adjustable both horizontally and vertically. The On/Off and Beam controls shall be switched from the train operator's console.
- (iii) Two bi- colour power LED based marker lights (tail lights) shall be provided which may be lit in both active and non-active cab. The tail lights shall be LED type. Each LED shall be dual colour of white and red which shall be selectable from cab. Alternatively, white & red LEDs may be provided within the same block/fitting and be used accordingly. In active cab the marker lights shall be white and in non-active cab it should be of red colour. During the normal train operation, white front lights shall glow and rear shall be red. However, in case of a stationary train in siding or depot, both front and rear lights shall be red.
- (iv) The taillights shall be sufficiently large and bright, to enable the lamp to be seen and acted upon by a train operator within the stopping distance of the consist travelling at maximum speed.
- (v) The control of Headlight and tail light shall be based upon the direction of train movement i.e. headlight and tail light (in white colour) should glow in the cab which is in moving direction and tail light (in red colour) should glow in the cab in the non moving direction.
- (vi) The headlights and taillights shall not be switched off when the train is passing through a neutral section.
- (vii) The Contractor shall propose to suitably indicate the front end of the train while parked at depot, or stabling sidings, by illuminating two white lights either by using dimmer position of head light or using dual colour LEDs in the tail light or by other appropriate means.

#### 12.8.3 Flasher Light

- (i) In order to attract the attention of the train operator of the following train or a train approaching from the opposite direction, in emergency, a powerful flashing amber light in addition to the tail lamps shall be provided in the front panel of each driving car. This light shall be switched ON by the train operator in case of emergency and shall not be switched OFF even while negotiating neutral sections. Provision should also be there to manually switch ON the flasher light as per operational requirement of Train Operator.
- (ii) Flasher light when lit and flashing shall be able to attract attention at a distance of 300m under clear sunny daylight.

#### 12.8.4 Door Indicator Lights

- (i) An amber indication lamp (power LED based) shall be located at an appropriate location near each door.
- (ii) The lamp shall remain extinguished when respective door is fully closed and locked.
- (iii) The lamp shall be illuminated when the door is in fully open condition, or when the locking mechanism has failed to register, preventing traction circuits from picking up or when the door is closed, locked and isolated.
- (iv) The lamp shall flash whenever door is opening or closing; for ex: when close announcement button from the active cab is pressed. It shall continue to flash till such time the door is closed.

#### 12.8.5 Call-On Light Switch

A Call-On Switch shall be provided in the train operator's cab, to cater for Emergency Push-Out situations. Operation of the switch on a failed train, with the Mode Selector in OFF, shall cause the tail lights at the rear of the failed train to flash on and off, indicating to the train operator of the rescuing train that he may proceed to affect coupling.

#### 12.9 Interior Illumination System

The lighting system shall generally conform to EN13272. The system shall be based on power LEDs and should meet following requirements in general:

- 1) The guaranteed life of the LEDs with their control system and optics/luminary shall not be less than 60000 burning hours.
- 2) The specified illumination level shall be met till at the end of the life of 60,000 hours when the illumination is not less than 70% of their original illumination level.
- 3) The colour of the LEDs shall be white (temperature 3000K). It shall be ensured that all LEDs are selected from same bin to avoid any difference in colour and performance.
- 4) The design of the heat dissipation arrangement shall be submitted in details with simulated results
- 5) Colour rendering index shall not be less than 80.
- 6) Complete light and energy simulation calculations shall be provided during design to prove validity of the proposed solution.
- 7) The system shall be designed to limit glare and ensure no glare by night time reflections in windows. Luminaries shall be designed to confirm relevant international standards.
- 8) The change of chromaticity over the lifetime of the product shall be within 0.007 on CIE 1976(u',v') diagram or equivalent.
- 9) Luminaire efficiency inclusive of LEDs/control gears & optics etc. shall not be less than 100 lm/W at the working junction temperature; higher values shall be preferred.
- 10) Design layout of LEDs & their strings/blocks should be such that the failure of one LED should not cause isolation of complete string/block. Similarly, failure of one controller on one string/block should not adversely affect other strings/blocks. Details shall be finalized during design stage.
- 11) Cars may remain unpowered in open sun and internal temperature may go up to 70°C (ERTS 3.10). Suitable protection measures shall be taken to ensure that this does not adversely affect the performance, reliability or efficiency of the lighting system and its components. Verification/validation to the above shall be proposed by the contractor during design.
- 12) Illumination within saloon with LED luminaires shall be designed so as to ensure that the desired maximum illumination level is achieved with LEDs operating at less than 50% of its rated capacity. However, driver/control unit/optics etc. shall be designed for full rating of the LEDs.
- 13) All luminaires shall be of LED type and fitting shall be protected and diffused. No exposed light sources will be accepted.
- 14) LED luminaires and control gears shall be sealed to at least IP 54, BS EN 60529:1992, to prevent the ingress of dirt and foreign objects.
- 15) After one year, two year and 60,000 operation hours, the colour temperature shall be within  $\pm 5\%$ ,  $\pm 8\%$  and  $\pm 10\%$  of the initial value respectively.
- 16) LED luminaries shall be designed to withstand switch cycles of 100,000 and test shall be conducted to prove the compliance.
- 17) The Contractor shall replace all the LED lighting with a newly improved LED lighting if
  - (i) The total cumulative failure rate of the LED luminaries and control gears within DLP exceeds 5% with 20% of LEDs failed in a LED luminaire is constituted as a failure of the LED luminaire;



- or
- (ii) The illumination level at floor level of any five trains drops below 90% of the initial values at the end of two-year operation but before the expiry of DLP.

Note: The illumination of LED shall be designed assuming 15 hours daily operation and 365 days of operations.

- 18) Since LED technology is fast evolving and the Rolling Stock supply is a long drawn process, Sub-Supplier shall commit to supply new generation of improved LEDs progressively and which should be compatible with the luminaries already supplied and installed. The Contractor shall regularly update the Engineer on this aspect during the manufacture.
- 19) Noise generated by the energised LED lighting, fixtures and ballast/control gear installed in a car shall not exceed 50 dBA when measured 1m from the equipment.
- 20) LEDs manufactured by reputed manufacturers shall only be used after taking the prior approval of the Engineer during Design Review.

For indigenization of "Luminaries and Lamps" as referred in ERGS clause 1.1.8, Table 1C shall imply fitting and PCBs etc. except LEDs of the LED lights.

- 21) LED(s) shall have lumen rating as 100 lumen/LED or above.
- 22) Maximum number of LEDs which a driver/power supply can feed shall not exceed 60 LEDs.
- 23) During commissioning and subsequently, it may be desirable to adjust the lux level to 250/200 in the saloon. Provision shall be made for adjustment of the lux level within saloon. At least three levels of adjustments i.e. 200 lux/250 lux/300 lux shall be provided in the saloon illumination design as a minimum. Details shall be discussed during design review.

The selection of Vender shall be made so as to optimize the design criteria as above.

#### 12.9.1 Saloon Illumination

- (i) Energy efficient, power LED based lights, in luminaries meeting flame, smoke and toxicity requirements shall be recessed into the ceiling panelling. The light fittings shall be simple, and arranged not to trap dirt, moisture and insects. Suitable sealing protection shall be incorporated to prevent ingress of dust etc. from AC ducts. The luminaries shall ensure to minimise the glare.
- (ii) All the saloon lights shall work on 110V DC.
- (iii) The size and number of light fittings with diffuser shall be sufficient to provide a sensibly constant level of illumination of 300lux at a height of 1.0 m above floor level, along the entire length of saloon. The complete scheme for saloon lighting including gangway area shall be decided during design stage,
- (iv) Separately protected lighting circuits shall be used, such that in the event of one tripping, the others provide evenly distributed lighting throughout the saloon.
- (v) In the elevated corridors, during daytime, the illumination level shall be controlled as per clause 12.9.1 (vii) below. 100% saloon lights shall glow in tunnel (if available) all the time and in elevated corridor during night. The changeover shall be automatic as well as driver actuated. Saloon/Emergency lights shall be supervised by TCMS. Contractor may propose an alternate proposal wherein all the LED lights may be ON but with varying intensity (current level) to match the requirements of Lux level according to ambient light condition during day and 100% intensity during night. An illumination controller would be required to be installed at car level to maintain the desired illumination level. Active dimming control with sensor count and sensor location details shall be submitted for Engineer's review and approval during design stage.
- (vi) 100% of lamps, evenly distributed over the saloon area, shall remain illuminated, energized even when the train / car passes through neutral section.
- (vii) The control logic shall ensure automatic selection, with manual over-ride, of the saloon light circuit(s) to maximize utilization of the natural light and maintain the desired illumination level. During daytime, the interior lights shall be controlled automatically through infinitely variable dimmer(s) (continuous and step less control) so as to maintain illumination level within acceptable level and reduce the energy consumption. The control of illumination intensity should be at car level with the multiple light sensor input to dimmer. The Contractor shall submit full details including the number of sensors, their location, control logic etc. for review by the Engineer during design stage.
- (viii) The Contractor shall submit service life of LED lamp during the design stage which shall be as per

the best international practices.

- (ix) The Contractor shall submit layout of fittings and control circuit for review by the Employer.
- (x) It shall be possible to replace defective LEDs/ block of LEDs with ease and minimum need for readjustments or otherwise. Any special tools required for the purpose shall be supplied as two sets to each depot.

#### 12.9.2 Cab Illumination

- (i) The cab shall be provided with ceiling lights, providing a sensibly constant level of illumination of 200lux at 1m above floor level. It shall be operated automatically by the opening of partition door of either driving console, and extinguished manually from within the cab.
- (ii) Separate lightning of the train operator's console shall meet the requirements of UIC 651 or which stipulates a minimum of 60 lumens/m<sup>2</sup> measured at the driving control desk. Driving console light shall be operated manually from within the cab.

12.9.3 All cubicles shall have sufficient lighting arrangement for facilitating their maintenance related works and it should be supplied from battery line, duly interlocked with door of that cubicle. Lighting in the cubicles for maintenance related works shall be made available even after isolation of control supply of the train.

#### 12.9.4 UTO/RM indicating light

One indicating light visible from side of the train indicating UTO or Restricted Manual mode status, shall be fitted on each side of the cab end.

- The switch off position shall indicate UTO not being used and safety for operation and maintenance personnel to board the train and/or to carry out coupling during rescue operation
- Switch ON would imply "train under UTO".
- Flashing would mean Restricted Mode activated.

### 12.10 Cab Equipment

#### 12.10.1 Master Controller

- (i) An ergonomically designed step less Master Controller shall be provided on the train operator's console. The Master Controller shall be a fore and aft longitudinal shift type. The overall design shall ensure minimal stress on train operator hand. A rotary type deadman's device shall be provided on the Master Controller Handle. The angle of rotation shall not be more than 15deg. There shall be adequate hysteresis between motoring/coasting/braking. Driving mode will be achieved by moving handle away from the operator and conversely braking mode shall involve pulling the handle toward the operator. Design shall ensure the master controller movement remains soft, uniform and undisturbed at least up to intermediate overhaul. No greasing or lubrication requirement shall be foreseen during this period.
- (ii) The Master Controller shall be provided with deadman's safety device and the deadman mechanism have auxiliary switches.
- (iii) The Master Controller shall have following positions:
  - Off
  - Emergency Brake Application
  - Motoring
  - Braking
- (iv) The Master Controller shall have adequate number of dedicated potential free interlocks solely for ATO and ATP system operation.
- (v) At least 10% spare contacts in master controller for each position and type shall be provided and wired up to the terminal block in the main electrical cubicles.

#### 12.10.2 Mode Selector

- (i) A Mode Selector Switch shall be provided on the train operator's console and selection of mode shall be by longitudinal, fore and aft movement.
- (ii) The Mode Selector shall be mechanically and electrically interlocked with the Master Controller.
- (iii) The Mode Selector shall confirm to the operational modes described at ERTS 12.2.
- (iv) At least 10% spare contacts in mode selector for each position and type shall be provided and wired up to the terminal block in the main electrical cubicles.



**12.10.3 Control Lock**

- (i) A control lock shall be provided in each control console (Master Controller), which shall be operated by the control key. The lock shall have two positions 'ON' and 'OFF'. The control key shall be removable in the 'OFF' position only.
- (ii) The control lock shall be of fail-safe design. The control lock element shall use appropriate feature to ensure that contacts cannot possibly remain closed when lock or the switch position indicate that they should be open.
- (iii) The control lock interlocking shall be of such strength that the mode selector handle and control key are sacrificial to the interlocking in the event either is subjected to excessive force.

**12.10.4 PWM Generator or MVB/Ethernet based traction/braking commands**

- (i) Robust design fail-safe redundant PWM generator shall be used to convert the analogue signal from the Master Controller to a PWM signal for powering and braking control. The design shall ensure no shifting of calibration once done during commissioning. The outgoing PWM signals shall be hardwired.
- (ii) The Contractor shall interface with Signalling Contractors for ATO operation interface.
- (iii) The equipment shall conform to IEC 60571, IEC 60077 and IEC 61373.

Alternatively, Contractor can offer MVB/Ethernet based traction/braking commands generation.

**12.10.5 Electrically operated Wind Screen and Detrainment Door Wiper**

- (i) Wipers for windscreen and detrainment door shall be provided at appropriate location for operable from the train operator's control panel.
- (ii) Wipers shall be electrically operated.
- (iii) The Contractor shall submit details of the system configuration and components like screen wiper blades, washer nozzle, the washing media, reservoir etc.
- (iv) Wiper control shall have the following modes of operation:
  - Slow speed
  - High speed
  - Wash mode
- (v) It shall be possible to operate one or both of the wipers in the operating cab.
- (vi) It shall be possible to operate wiper from active cab only.

**12.10.6 Electric Horn**

Two electric horns, one having high tone and other low tone, operable from the train operator's console shall be provided, located at the front end of the cab, facing forwards. Technical details of the horns shall be submitted for review by the Engineer.

12.10.7 The layout of the cab control equipment shall be as per applicable international standards/norms. The relevant details shall be provided to the Contractor by the Engineer.

12.10.8 Train operator shall have full view of displays and controls in the cab in both seated and standing positions. The controls and indicators inside the cab shall be decided during detail design stage based on current practices.

**12.11 Auxiliary Machines and Drives**

- 12.11.1 With the exception of the auxiliary (pantograph, etc.) compressor, which shall be suitable for a supply at 110V DC all other drive machines shall be suitable for (non-operational sinusoidal) supply from an auxiliary converter, which will have harmonics.
- 12.11.2 The motors shall be totally enclosed with sealed for life permanently lubricated ball bearings, self-cooled, heavy-duty devices, designed for energy efficiency and long life. Each motor shall incorporate suitable protection measures.
- 12.11.3 Motors shall be suitable for the designed maximum load and maximum ambient temperatures to ensure that the motors have designed life of thirty five years.
- 12.11.4 All auxiliary motors, including that of the auxiliary compressor, shall conform to the requirements of

IEC 60349-2.

12.11.5 The temperature rise limits of all auxiliary motors shall be to the maximum temperature index, minus 70°C. The temperature rise test of the auxiliary converter shall be simultaneously carried out with auxiliary converter and all auxiliary motors.

12.12 Deleted.

### 12.13 Deliverables

12.13.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	12.4.9 (ii)	Relay Testing Kit as per clause 12.4.9 (ii).	Two nos. in each depot.
2.	12.4.9 (iii)	Tools for extension of relay base as per clause 12.4.9 (iii).	Two nos. for each type of relay in each depot.
3.	12.4.9 (iv)	Dummy relay (test switch).	One no. for each type of relay in each depot.
4.	12.8.1 (iv)	Facility for replacement of power LED clusters used as exterior lights.	In each depot.
5.	12.8.2 (i)	Facility for replacement of power LED clusters used as head and tail lights	In each depot.
6.	12.9.1 (x)	Special tool for replacement of defective LEDs/ block of LEDs	Two sets to each depot.

#### Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



**13. COMMUNICATION SYSTEM****13.1 Train Communication Equipment**

13.1.1 The following on-train communications requirements shall be provided:

- (i) Two-way Communication between the Operations Control Centre (OCC) and train operator, via train radio equipment (Supplied by Communication Contractor).
- (ii) Means for pre-recorded (manual/automatic), live (other than pre-recorded) Passenger Announcements on the train by OCC via train radio system (Supplied by Communication Contractor).
- (iii) Means for the train operator to address passengers including announcements etc. throughout the train from the driving and non-driving cab.
- (iv) Means for the train operator & OCC to address passenger including announcements etc. in two coupled trains.
- (v) Facilities to permit duplex conversation between a passenger who has operated a Passenger Alarm Device (PAD), and the train operator/OCC.
- (vi) Facilities for duplex conversation between Train Operator(s) in two coupled trains.
- (vii) An automatic voice announcement system.
- (viii) A Public Address and Passenger Information System (PA & PIS).
- (ix) Passenger saloon surveillance system (PSSS).
- (x) Door opening / closing chime and announcement.
- (xi) Complete tools including Software, Hardware, equipment etc. for configuring, editing and creating route /station data, announcements, messages & fonts, audio speech and interface of the system with other sub systems etc. shall be supplied. It shall be possible for the Engineer to configure the PA, PIS & PSSS software for implementing operational & maintenance related modifications. Software tools for recording and analysing interface signals shall also be provided.

Full access to the software for the purpose above shall be provided. Any hardware/software tool required for this purpose shall also be provided. The documentation including but not restricted to flow charts (for complete software), signal flows, and interpretation of signal etc. shall be provided. Engineer shall be fully trained and made fully conversant by the Contractor for this purpose.

- (xii) PA & PIS system shall have full flexibility and dynamic compatibility with any number of short loops/route changes which may be enforced during operation. Necessary interface with signalling system shall be ensured.
- (xiii) All the interface signals relevant for PA & PIS system shall be recorded with time stamp.
- (xiv) PA, PIS & PSSS System shall be designed to cater any single point of failure. Functionality at car/train level (as applicable) shall not be affected due to any type of single point of failure. Adequate redundancy shall be built in the proposed system architecture. Full details shall be submitted for review and approval by Engineer at the time of design approval.
- (xv) PA, PIS & PSSS shall have latest state of the art communication protocol. Provenness of the system shall be ensured by the Contractor. Full details shall be submitted for review by the Engineer.
- (xvi) Single point upload and download of data, software etc. for all PA, PIS & PSSS system shall be provided by the Contractor, along with the provision of remote upload/download. Full details shall be submitted for review by the Engineer during detailed design stage.
- (xvii) PA/PIS & PSSS equipment/cubicles shall be of at least IP53 or better class. Complete details of available IP protection of all PA/PIS & PSSS system's equipment shall be submitted and get approved by the Engineer. Exterior equipment shall be of at least IP65. Any degradation based on technical difficulty or recommendation by OEM shall be reviewed by the Engineer during the design.
- (xviii) Suitable interface of PA, PIS & PSSS for synchronizing time with TCMS shall be ensured by RS Contractor.
- (xix) Any other equipment required onboard for interfacing with the other designated Contractors viz. Signaling, Telecom and others for operation of trains, under UTO mode shall be provided by the Contractor.
- (xx) Provision of self-checking & its result for all PA, PIS & PSSS equipment shall be ensured. Facility

for checking live health status of equipment on VDU shall also be made available. Full details shall be submitted for review and approval by the Engineer.

- (xxi) PA, PIS and PSSS equipment shall have the provision of multilingual system wherever required.
- (xxii) Cables for PA, PIS and PSSS shall be suitably insulated, screened, armoured and overall outer sheathed. These cables shall also be of fire survival, fire retardant/resistant type. Full details of standard along with relevant catalogue etc. shall be submitted for review and approval.
- (xxiii) Fire & Smoke compliance in line with EN45545 part 1 to 7 for complete PA, PIS & PSSS shall be submitted for review by the Engineer.

### 13.2 OCC to Train operator and On-train Public Address Communication Link

13.2.1 A Train-to-OCC radio communications link (supplied by the Communication Contractor) shall be provided to enable:

- (i) Voice communication between the OCC and passengers, and between the OCC and the train operator.
- (ii) Vehicle health data communication from TCMS to OCC at designated times and locations. The data required to be transferred from the train to the OCC shall be finalised by the Contractor at the detailed design stage and submitted for review by the Engineer. Provision for sending train data at end of every trip shall also be ensured by the Contractor.
- (iii) The interface between the radio link and TCMS/PA/PIS/PSSS shall be provided by the Contractor. Interface Control Document (ICD) shall be submitted for review.
- (iv) Voice shall have priority over data communication.
- (v) When the OCC to passenger communication occurs, any other system set at that time shall be overridden.
- (vi) A radio control head, which shall be integrated with the driving console, shall be supplied by Communication Contractor. The mounting location shall be carefully planned as the equipment is frequently used by the Train Operators. Details of the equipment & its mounting location shall be submitted to the Engineer for review before finalization & implementation.

13.2.2 A suitable interface shall be provided by the Contractor to enable the OCC-to-Passengers announcements to be transmitted over the train public address system.

13.2.3 Adequate space and reliable battery backed power supply shall be provided to communication Contractor for the on-board radio system.

13.2.4 Facilities to permit announcements in the train along with the provision for communication with OCC by Roving Attendant through train radio shall be provided. Suitable interface in line with Appendix TD clause 3.10.4.1 shall be ensured along with submission of full details for review by the Engineer.

### 13.3 Passenger & OCC Alarm

13.3.1 There shall be four passenger alarm devices (PAD)/Passenger Emergency Alarm (PEA) in each car.

13.3.2 When a passenger alarm device is operated, a warning sonic device shall sound in the driving console/OCC, an indication shall be given to the train operator/OCC of the location of the operated device, automatic views from surveillance cameras provided near the location of activated PEA shall be displayed in the monitors inside cab / OCC. Rolling Stock Contractor shall also ensure the following provisions:

- (i) A visual indication on the exterior of the car shall advise station staff which is the affected car.
- (ii) The train operator/OCC shall acknowledge the alarm by operation of an override device in non UTO/UTO operation respectively, which shall terminate the cab sonic alarm, and simultaneously cause an indicator to illuminate at the emergency device location.

It shall be feasible for train operator/OCC to acknowledge and isolate/reset the specific PEA from the driving console/OCC after verifying the conditions in the saloon to his satisfaction through CCTV images which shall be recorded with date, time, train ID/No., rake ID, Camera Name/Camera ID, geographical location, PAD location, event stamping etc.



Recording of image upon certain critical events shall be as per ERTS 13.9.11.

- (iii) Passenger communication shall be train operator/OCC initiated. This will render the local microphone and loudspeaker adjacent to the activated emergency device/OCC active, thereby enabling bi-directional inter-communication between the train operator/OCC and the passenger. Once pressed/operated, it shall be possible for the commuter to communicate with the Train Operator/OCC unless inhibited by the Train Operator/OCC.
- (iv) A fall back system shall be provided to enable the communication between Train Operator/OCC & passengers with PEA in case of failure of normal communication channel. If more than one emergency device has been operated, each demand shall be independently acknowledged, and alarms shall be stored, displayed and answered sequentially.

Full details shall be submitted for review by the Engineer.

- 13.3.3 Whilst the communication system is in the passenger alarm mode it shall be possible for the train operator/OCC to move between passenger alarm, train operator/OCC, PA and cab-to-cab communication.

In the event that the train operator/OCC fails to acknowledge a passenger alarm call, within a specified time, the call shall be logged by TCMS. TCMS shall be provided with following data relating to the passenger emergency alarm:

Current status of each passenger alarm button.

Alarm event for each passenger alarm button, clearing when acknowledged by the train operator/OCC.

- 13.3.3.1 Once the doors have been opened, it shall not be possible to restart the train until all the passenger alarms have been reset from OCC/driver's cab. Once this has occurred the system shall revert to its normal form of operation.

Provision of bypass for enabling traction if required or as decided by the Engineer shall also be provided. Full details shall be submitted for review and shall be discussed during design stage.

Screened cable pairs of fire survival type shall be provided for the passenger alarm system.

- 13.3.4 Under no circumstances shall cab-to-cab conversation or train operator to OCC conversation be relayed to any passenger.

- 13.3.5 The PEA push button once pressed should be resettable from remote i.e. from the operating console or OCC. When train is operating in UTO mode, two way communication shall be established with OCC.

- 13.3.6 The activation of any PEA shall interface with the saloon CCTV such that images of concerned area are automatically displayed on train-borne display unit inside the cab and transmitted to OCC. It shall be possible to OCC to identify which PEA has been activated so that the communication with the passengers can be initiated.

Automatic transmission of CCTV images for live streaming at OCC and creation of historic data (5 min before and 15 min after the event or as discussed with the Engineer during design stage) shall be as per ERTS 13.9.11. Historic data period shall be customizable. Full details shall be submitted for review and approval by the Engineer.

- 13.3.7 Multilingual (regional language(s) and English and/or Hindi) indication of indicators shall be provided on PEA speaker panel (like wait, call, Talk etc.). The indication shall be separate from Labels & Signage provided for the operation & function of PEA. Necessary indication to commuters shall also be made available in case of faulty PAD/PEA.

- 13.3.8 PEA communication system shall be SIL2 compliant except for voice signals.

- 13.3.9 Speaker/mic panel provided for PEA shall be flushed with carbody wall to have good aesthetic. Details shall be submitted for review by the engineer.

#### 13.4 On-train Public Address

- 13.4.1 An integrated main communications panel shall be provided at the driving side of the cab by the Contractor to control the public address functions, cab-to-cab communications, and passenger alarm communications. This panel shall have a backlit LED display with facilities for the touch screen input, capable of handling multilingual (regional language(s) and English and/or Hindi)

- characters. Full details shall be submitted for review by the Engineer.
- 13.4.2 On-train public address shall be capable of being initiated from the OCC, the driving cab or the Automatic Voice Announcement System (AVAS). The Automatic Voice System shall be the default public address mode (default mode).
- 13.4.3 The microphone to be used for public address / announcements from Cab and OCC should have high dynamic noise canceling feature. The contractor shall submit the details of the microphone for review by the Engineer.
- 13.4.4 The Public Address System together with its main components shall comply with internationally accepted standards.
- 13.4.5 Power amplifiers are required for the PA system and shall cater for the requirements of complete train.
- 13.4.6 Power amplifiers are required for the PA system and shall be provided in each car. Each power amplifier shall feed 50% of the speakers in the same car and 50% in the adjoining car, to ensure that in the event of a single power amplifier failure, at least half of the speakers are still operative in the car. Full details shall be submitted for review by the Engineer.
- 13.4.7 The number, positioning and output of each loudspeaker and power amplifier shall be designed such that an even sound coverage in all areas of the passenger saloon is achieved. The sound pressure level when measured at a height of 1.5m above the floor shall not vary by more than 3dB along the entire length of the consist. At least 12 number of saloon speakers shall be provided in each car. Loudspeakers shall be positioned to give uniform distribution of sound pressure level. Full details along with simulation shall be submitted for review and approval by the Engineer.
- 13.4.8 Adequate number of exterior speakers in order to warn/aware the passengers/commuters while boarding/de-boarding shall also be provided.
- 13.4.9 The PA system shall have automatic continuous variable volume control, based on saloon background noise level. A sound level adjustable between 6dB(A) and 10dB(A) above background noise level is required throughout the train. The Contractor may however, propose alternative/ suitable settings. The Contractor shall supply software / hardware configurator for enabling the Employer's personnel carry out the adjustment as per the proposed system. Full details shall be submitted for review by the Engineer.
- 13.4.10 The PA system shall exhibit no oscillation, acoustical feedback or other instabilities at any combination of input level, gain or speaker volume control settings under all test and operational conditions.
- 13.4.11 The public address amplifiers shall be protected against short circuit at the outputs of the amplifier.
- 13.4.12 Any enclosure, if required for exterior speakers' material, shall be of at least SUS-304 or better SS grade in order to avoid any corrosion. Equipment shall be at least IP 65 or better. Full details shall also be submitted for review by the Engineer.
- 13.4.13 Deleted.
- 13.4.14 Deleted.
- 13.4.15 Suitable provision to adjust the volume independently for the announcements, external chimes internal chimes, interior speaker, driving console speaker, exterior speaker shall be provided for the Train Operator. Further adjustment (if required), easy access to potentiometers or equipment provided for the adjustment of volume for speakers shall be ensured for maintenance personnel. Full details shall be submitted for review and approval by the Engineer.
- 13.5 Cab to Cab Mode**
- 13.5.1 In the cab-to-cab mode, the train operator shall be able to communicate with a person at the other end of the train or with the train operator(s) of a train coupled to this train (e.g. to undertake a push-out). Two way communication shall be established in this mode.
- 13.5.2 The cab-to-cab communication system shall be able to operate independently of, and simultaneously with, automatic announcements and with the passenger alarm system operative.
- 13.5.3 Duplex mode operation between two trains while in proximity shall be possible, via OCC on the radio communication system (supplied by Communications Contractor).
- 13.5.4 The Contractor shall submit procedure for review of the Engineer.



- 13.5.5 It shall be possible for Train operator to adjust the volume in the cab.
- 13.5.6 In case of train coupled, train operator(s) shall be able to communicate with a person available in other cab(s). Communication with the passenger from any of the Cab(s)/OCC shall also be made available. Full details shall also be submitted for review by the Engineer.

### 13.6 Automatic Voice Announcement System (AVAS)

- 13.6.1 An automatic pre-recorded message announcing system shall be provided in front and rear car of the train by the Contractor. Functions and features of this system shall be as follows:

- (i) One device shall be provided in front and rear car of the train which shall be on hot standby. In case of failure of the identified master, the device at the other end shall automatically become master. The device shall be operable from the train operator's cab (for UTO, equipment shall be properly concealed in the driving desk).
- (ii) The Automatic Voice Announcement System shall be fully integrated with the On-train PA system. Any failure of component which can adversely affect functionality shall be logged by the system itself and also be communicated to TCMS for reporting to the train operator and data logging. Full details shall be submitted for review by the Engineer.
- (iii) The pre-determined messages (voice announcements and text messages) shall be automatically triggered by train events and / or the ATP/ATO system to make an announcement. Close liaisoning is required between the Contractor and the Signalling Contractors in this regard. Full details shall be submitted for review by the Engineer.
- (iv) All the hardware requirements to achieve interfaces between the Automatic Voice Announcement System and the ATP/ATO system shall be provided by the Contractor.
- (v) Voice announcements and text messages for the displays shall be pre-recorded and configured into the system using the "off line" speech and route database editor. Messages, audio or visual or both shall be multilingual (regional language(s) and English and/or Hindi). Messages shall be recorded in the voice of professionals Announcers to be approved by the Employer.

The hardware and dedicated software etc. for editing, creating and modifying the speech and route database shall be handed over to Employer at an appropriate time, during the Contract period, and shall be decided during the design stage. The Employer's staff shall be associated during the editing activity. Messages shall be digitally stored. Provision for adding /expunging / editing any type of message shall also be ensured. Necessary tools shall also be handed over at an appropriate time.

- (vi) The Automatic Voice Announcement System shall also be equipped with display and announcement of computer generated messages. The Contractor shall provide equipment and means to achieve this by Employer's maintenance personnel.
- (vii) The comprehensive details (their format, frequency, use etc.) of message and special messages (to be triggered manually) shall be subject to review by the Engineer.
- (viii) A door open and door close announcement followed by a chime shall be triggered automatically and shall be synchronised with the door operation. Close liaisoning is required between the Rolling Stock Contractor & Signalling Contractor. Also, a "Door Close Announcement" button shall be provided to trigger door close announcement followed by a chime.

Suitable arrangement for door close announcement in case of slave to master or vice versa of hot stand by equipment shall also be ensured by the Rolling Stock Contractor.

The door close chime shall continue to play till the Doors achieve locked position. Similarly, a chime shall be played during the door opening. During this time, any existing auto announcement shall be aborted. The chime shall warn the passengers inside the train as well as those on the platform about the door operation. The adjustment of volume of the chime shall be independent of the volume of the announcements.

In case of obstruction in particular door(s), the chime on the corresponding car/door(s) shall only be broadcasted.

Independent volume adjustment of external chime, internal chime, announcement volume, exterior speaker volume, saloon speaker volume shall also be provided. Full details shall be submitted for review by the Engineer.

- (ix) The system shall be capable of storing 120 minutes of pre-recorded messages preferably in digital MP3 format or a latest format. The memory shall be able to store Route Database for at least 200 stations. However, it shall be possible to enhance the memory by expansion using commercially



available memory devices. Full details shall be submitted for review by the Engineer.

- (x) It is proposed to provide commercial / general audio and/or visual messages/video in between the announcements. The system shall be capable of playing / displaying of such advertisements (including videos). Details shall be submitted for review by the Engineer.
- (xi) In case of train parting, both cab's automatic voice announcement system shall become active and it shall be possible to make an announcement from either of the Cab and from OCC.
- (xii) In case of non-closure of any door, the chime shall continue for the effected car only.

### 13.7 Passenger Information System

#### 13.7.1 General

- (i) The Passenger Information System shall include a high resolution multi colour graphic display, suitable for the remote displaying of moving messages, in multilingual (regional language(s) and English and/or Hindi), on board the train, in the passenger area. The colour of multilingual (regional language(s) and English and/or Hindi) character shall be approved by the Engineer. Emergency announcements may be displayed in red.

6 no. of LCD with LED backlit programmable displays (approximate length of 37 inches and the width shall be in line with the side coving panel width) with adequate protection from vandalism shall be provided in each saloon (location shall be decided during mock-up review). Details of available size of displays and mounting locations shall be discussed during design stage. These displays shall be used for messages/ advertisements (incl. video) etc which shall be downloadable from one end of the car/unit and/or from the cab. Provision shall be made for remote downloading as well. Provision shall be made to install equal number of LCD panel with LED backlit displays in future by the Employer by simply connecting it to the system. Size and location of provisional displays shall be decided during design stage. Any wiring etc. if need to be provided, shall be ensured. The Employer shall be able to interface and commission such screens at these locations. The location & size shall be decided during design. The displays shall be commercially available and work on open/commercial protocols. The colour combination of the display content should be such that these may be distinguished by colour blind person.

- (ii) The location and number of the display units shall be proposed by the Contractor taking into consideration the need for all-round good visibility by passengers within the saloon/platform. The Contractor shall submit proposal, including diagrammatic representation of the angle of visibility of the display units.
- (iii) There shall be a Destination Indicator behind operator cab's wind screen. The destination indicator shall be capable of displaying two lines of multilingual messages. The top line shall display characters in regional language(s) of at least 90 mm height while the second line shall display Hindi and/or English characters of at least 45 mm height with yellow LEDs. The Contractor shall submit proposal for Engineer's review.
- (iv) There shall be a Train Number Indicator similar to the 'Destination Indicator' behind operator cab's wind screen. The Train Number Indicator shall be capable of displaying up to 6 digit alpha-numeric train ID. The Contractor shall submit proposal for Engineer's review. Suitable interface to ensure alpha-numeric Train ID shall be ensured with designated Contractors.
- (v) There shall be an External Side Destination Indicator on each side [capable of displaying multilingual (regional language(s) and English and/or Hindi) displays, to be decided during design stage] of every car, at an appropriate location close to mid point of the vehicle but beyond the sweep of the passenger saloon doors. The destination Indicator shall display the destination name to the passengers standing on the platform. It shall be capable of displaying the requisite information in single line alternating between in regional and Hindi and/or English language(s). The device shall be flush mounted with the exterior of the car body. The display shall automatically change as per short loop operation as the case may be.

Interface with designated PSD Contractor shall be ensured to finalize the location of external displays in order to get clear view of displays by Passengers on platform.

- (vi) The Destination Indicators and Train Identification Indicator shall be able to be set via the route setting control. The route setting control shall be either through the manual control on the TCMS or be automatically set by the Automatic Train Control (ATP /ATO) system as given in Appendix TD.
- (vii) The Train Number, Destination Indicator and Train Identification Indicator shall have a view angle of not less than 120 degrees in the horizontal plane and shall be legible under direct sunlight,



- artificial light and darkness. Light sensors shall be equipped to vary the intensity of the LEDs based on the level of ambient light.
- (viii) The Destination Indicator, External Side Destination Indicator and Train Number Indicator shall have pixel diameter of 3 mm and pixel per pitch shall not be greater than from 4 mm. Alternative displays panel configurations may also be considered for better resolution. The Contractor shall submit the proposal for review of the Engineer.
- (ix) Size and location of Destination Indicator, External side Destination indicator and Train number indicator shall be optimized as much as possible with reference to mounting location. Details shall be submitted for review by the Engineer.
- Location & size of all the displays shall be reviewed during mock-up review.
- (x) Programmable Digital Route Maps (DRM):
- Four programmable coloured LCD with LED backlit based route maps for the respective lines shall be provided above saloon door, gangway ends etc. and shall have following provisions as minimum. Details shall be decided during design:
- Display of destination station, present station, approaching station, distance for reaching next stations, real time clock and door indications etc. Necessary interface shall be ensured by the Contractor.  
Route-map of respective lines in different colours, point of inter-change or any other important information, flashing of emergency messages, important train messages, scrolling of routes, adding/ expunging of stations, selectable display of route.
  - The size of the letter on LCD with LED backlit displays panel and resolution shall be programmable and have adequate clarity and visibility for a seating passenger. Further details shall be decided during design.
  - Direction of movement of displays, positioning of destination station on DRM shall match with the geographical direction of destination station/train direction.
  - The station names shall be displayed in multi-languages (regional language(s) and English and/or Hindi) alternatively.
  - DRM display size has to be much longer to give comfortable view of the complete line(s) and additional information as already described above. DRM display shall fully use the available space in the door coving where the same shall be mounted.  
Provision shall also be made to install equal number of LCD with LED backlit display in future by the Employer by simply connecting it to the system. Size and location of the provisional displays shall be decided during design.  
Detail specification shall be drawn and screens shall be got approved during design. Additional changes if required during design shall be incorporated during design.
  - Door indication on DRM shall be discussed during the design stage and is likely to be different on each DRM due to its mounting location. Details shall be submitted for review by the engineer.
  - Routes map, arrows, lines etc. shall be dynamically updated based on the train location.
- (xi) Provision for setting up of a PA/PIS Lab in each Depot for programming of all displays including DRM shall be ensured by the Contractor. Full facilities including any hardware/software tools for programming the displays and system shall be supplied to each Depot. Employer's engineers shall be fully trained to programme, edit and interface the display panels with the system.
- (xii) The external displays shall have adequate brightness which shall have auto adjustment with the outside ambient light.
- 13.7.2 Programmable split screens of all Displays (LCD with LED backlit) capable of displaying different messages, advertisements (including videos) etc. in each split shall be provided. Full details shall be submitted for review by the Engineer.

- 13.7.3 Size & location of all the displays shall be optimized as much as possible with reference to the mounting location. Details shall be submitted for review and approval by the Engineer.
- 13.7.4 Layout of fully programmable displays shall be discussed during the design. Any requirement for the decision on layout shall be suitable taken care by the RS contractor.
- 13.7.5 Displays & system shall be capable for displaying live videos like news, sports etc. full details shall be discussed during the design.
- 13.7.6 There shall be no limitations on assigning different files (including video, gif etc.) on the programmable displays split screens.

### 13.8 Operation of Passenger Information and Automatic Announcement System

#### 13.8.1 Automatic Operation of Passenger Information System

- (i) The system shall be capable of automatic operation throughout. At train set up, the train number provided by ATO/ATP shall automatically select the route to initialise the passenger information system by selecting the appropriate information from the train equipment and transmitting it to speakers and displays. The train operator shall be able to over-ride the automatically supplied train number and when no automatic route selection is given shall be able to enter the train route.
- (ii) The system shall update the journey information by accessing the train location information from the ATO/ATP equipment. The Automatic Announcement and the Passenger Information System systems shall at all times provide the same route, destination and next stop information to the passengers. The Automatic Announcement and the Passenger Information System shall indicate which side of the car that the doors will open at the next station stop
- (iii) The system shall be capable of receiving real time information from the control centre relating to delays and other relevant information. The system shall be capable of automatically updating the information being presented at the time to include the real time information received without the train operator's intervention.
- (iv) Planned and Unplanned skip station operation & announcements at appropriate location & station shall also be available. Necessary interface shall be ensured by the Contractor. Full details shall be submitted for review by Engineer.

#### 13.8.2 Manual System

- (i) In addition to automatic operation, visual and audio information shall be capable of being originated from the train operator's cab. The system shall be capable of making pre-recorded announcements (both audio and visual) by manual triggering from main communications panel in the event that the ATO/ATP positional information is not available. Under such circumstances, messages shall operate automatically for the route from the TCMS information. Messages and announcements shall be triggered based on distance travelled and door operations. Manual override shall be provided to allow for station skipping. The train operator shall be able to override the automatic system and select message to be broadcasted randomly. All activation criteria shall be submitted for review by the Engineer.
- (ii) In case of system degradation, train operator shall be able to make manual announcements through microphone from the cab.

#### 13.8.3 Audio Recorder

An automatic recorder shall be provided to record all automatic announcements made by PA system in saloon, manual announcements through MOP/AOP in saloon, announcements made by OCC in saloon (train), announcement made by roving attendant, conversation between cab to cab and conversation between passenger (recorded PEA wise with time stamp) & train operator when Passenger emergency alarm is activated in MP3 format or any other superior format. It shall be possible to download the recorded data without using any special tool/equipment directly from the recorder. The recorder shall have expandable memory to store the data for at least three days in revenue service."

### 13.9 Passenger Saloon Surveillance System

- 13.9.1 The Passenger Saloon Surveillance System (PSSS) shall comprise of a close circuit television (CCTV) network using surveillance cameras, routers and cables, monitors and other accessories. The fully expended system shall be designed for minimum 25fps or more. The picture quality will be level E as minimum at 100% Rotakin measured according to EN50132-7. The design shall be finalized during design stage.



13.9.2. Each car shall be provided with at least four surveillance camera devices at appropriate location to cover the maximum passenger saloon area for surveillance. It shall be possible to increase number of cameras by at least 2 per train by simple plug in to the system. The wiring and end connector to mount camera in cab(s) and mounting arrangement complete in all respect, but masked, shall be provided. Any additional tool hardware/software required for expanding the system shall be provided to enable the Employer to plug in the cameras if so required in future. Employer's Engineers shall be trained for interfacing and commission the same.

The camera shall be suitably selected in respect of best HD resolution, clarity of images, illumination conditions, iris control, Wide Dynamic Range (WDR) etc. for on-train applications and shall be of proven design. The design of camera shall be finalized during design stage. Mounting of camera shall be unobtrusive, flushed with, or recessed into the interior panel. Screen shall have facility to enable multiple views of the platform simultaneously.

The system shall be based on open environment/protocol like Ethernet for ensuring interchangeability of cameras. The system shall have self diagnostics and communicate the same suitably to the Train Operator/maintainer.

13.9.3 Additional camera(s) shall be placed on outer sides per two cars as minimum for gathering rear view of the platform. Selection of type and number of cameras shall be finalized during design and shall ensure clear view of passengers on platform to Train Operator, before start at each station till train leaves the platform completely. The system shall automatically switch to rear view when the train stops and will go back to default mode after the train leaves the platform. Train operator shall have full flexibility in selection of camera(s) as per his need. Suitable icons on the monitor shall be provided to monitor all the cameras as required by train operator. The HMI screen shall be large enough to accommodate with acceptable clarity simultaneous view up to four(selectable) rear view/saloon cameras.

13.9.4 Interface with designated contractor for PSD shall be ensured to finalize the location of outside camera in order to get clear view of passenger on platform to train operator.

13.9.5 TCMS HMI screen can be used as CCTV screen on demand or event actuated. The TCMS screen shall have provision to have to show simultaneous multiple views of CCTV/TCMS/PA/PIS. The final screen shall be decided during design.

13.9.6 Under normal operation, the views gathered from each of the camera located in the train shall be sequentially played in the monitor screens of both the cabs. Adequate controls shall be provided for necessary surveillance requirements and priorities.

13.9.7 In case of activation of PEA in any of the cars, the views from camera provided near the location of activated PEA shall be automatically displayed in the monitors. However, the train operator shall be able to select any other camera, as required. The cameras shall have inbuilt digital zoom function. It shall be possible to filter, zoom and select images in off line mode for investigation purpose. The images shall be with time stamping and it shall be possible to link them with respective location of train.

13.9.8 Similarly, in case of certain critical events like opening of Emergency door, Fire & Smoke, opening of driver console desk, Obstacle detected by saloon door or by obstruction deflection device, ADD (Auto-Dropping Device) track/catenary/infrastructure related events etc. the camera(s) shall focus and alert the train operator/OCC by automatically flashing the image(Refer Clause TD 3.1.20 of Appendix TD). Full details shall be submitted for Engineer's review.

13.9.9 Full details for automatic pop-up of images at OCC shall be submitted for review by the Engineer.

13.9.10 Each camera shall have recording capacity of at least 24 hrs.

13.9.11 The visual images from each camera shall be recorded in non volatile SSD memory in a video recorder without any limitation of repetitive writing of the data. The capacity of the recorder shall be of at least 7 days and shall have the provision of First in First out (FIFO). The memory shall be expandable by simple plug in of commercially available memory media. The records shall be easily downloadable. The Contractor shall provide equipment and means for the same. At least one set of such equipment shall be provided to each depot.

13.9.12 Provision shall be made and tested to store relayed CCTV images to dedicated server at OCC and depot in case of emergency or on demand. Storage device shall be of SSD type. Separate server for this purpose shall be provided by the contractor. The radio communication used for CBTC/CCTV may be used for relaying the images as above. As a minimum, the images should be selectable for

a time or time interval as required. Final scheme shall be worked out during design. The contractor shall provide the on-board equipment and commission the system based on the communication link provided by the Employer.

Full details shall be submitted for Engineer's review.

13.9.13 Facility to transfer historic data (5 min pre and 15 min post recorded CCTV feeds or as discussed with the Engineer during design stage) on demand from train to OCC shall also be possible from OCC. Necessary provision in terms of playing the historic data in OCC along with sufficient storage capacity of 2 TB shall be ensured in CCTV server. Provision shall also be made to retrieve all historic data of last 7 days in one go from CCTV Server at OCC. Full details shall be discussed during the design.

The CCTV recordings 5 minutes prior and up to 15 minutes after the event shall be so stored that these are retrievable as a single data file for each event.

13.9.14 Two way, duplex, communication between saloon CCTV/Cab front CCTV and OCC shall be provided. CCTV images shall be transmitted to the driving console through IP network and to OCC, on demand through communication link on real time basis.

13.9.15 The events which shall automatic trigger OCC viewing and considered essential for UTO operation shall be discussed and decided by the Engineer during detail design stage.

13.9.16 During such event(s) as mentioned above, the recording speed & view of the associated cameras will change from low to high speed. Full details shall be submitted for Engineer's review.

13.9.17 Additional camera(s) for gathering front end view, track, ODD (Obstruction Deflection Device) conditions and detrainment process view camera shall be provided by the Contractor. Suitable high sensitive camera(s) capable to record at low light shall be ensured. Full details shall be submitted for review by the Engineer. Selection and type/number of the camera shall be finalized during design stage.

13.9.18 Outside camera enclosure material shall be better grade to avoid any corrosion effect. Suitable dust & water/moisture protection shall also be ensured by the Contractor.

13.9.19 Details of storage module used for PA/PIS & PSSS and its capacity, limitation (if any) shall be submitted for review by the Engineer. Storage module/USB version used shall be of latest version & latest art of technology.

13.9.20 Suitable provision for monitoring of track, pantograph, OHE shall be in line with ERTS Clause 12.2.1(B)(k). Full details shall be discussed during the design stage.

### 13.10 PA/PIS & PSSS Test

13.10.1 All electronic equipment used shall be tested in line with ERTS 14.12 and shall also confirm to climate and environmental condition as stipulated in ERTS 3.10.

13.10.2 Details in line with ERTS chapter 14 shall also be submitted for review by the Engineer.

### 13.11 Interface

13.11.1 Appropriate interfacing with TCMS shall be developed to carry out the abovementioned functionality. The interface shall include provision of single point downloading the data logs stored in the memory of all train based Communication Equipment using TCMS interface.

13.11.2 See Appendix TD for full details of the division of responsibility between the Rolling Stock Contractor and Signalling Contractors.

13.11.3 Contractor shall provide adequate tools (two sets) and also impart training to Employer's Engineers for modifying/adding etc. the station names as well as audio visual announcements without changing the complete software.

13.11.4 Wi-Fi internet facility in train shall be installed by Designated Contractor. Rolling Stock Contractor shall install CAT 7 standard communication cable or latest standard cable. Complete cabling to access points, router, and internet antennae etc. shall be carried out by Rolling Stock Contractor. Full details shall be submitted for review by the Engineer.



- 13.11.5 Provision of dynamic bandwidth and its optimization for different uses shall be ensured suitable. Details shall be submitted for review by the Engineer.
- 13.11.6 Provision of displaying live news, sports etc. shall be ensured suitably. Details shall be submitted for review by the engineer.
- 13.11.7 Provision of remote update of display content shall be ensured suitably. Details shall be submitted for review by the Engineer.
- 13.11.8 Mounting location of train radio equipment shall be suitably chosen.

### 13.12 Set-up facilities for PA, PIS & PSSS:

Rolling Stock Contractor shall facilitate the necessary set-up in Depots for following:

- Complete integrated tools, hardware, software, equipment etc. for checking each functionality (as decided by the Engineer) of all the equipment.
- Fault diagnostic, repair centre etc. for the for each equipment with necessary training to Employer's Engineers.
- Necessary set-up including Software, Hardware, Equipment etc. to realise the change/modification shall also be ensured by the contractor.
- Provision for setting up of a PA/PIS Lab in each Depot for programming of all displays including DRM shall be ensured by the Contractor. Full facilities including any hardware/software tools for programming the displays and system shall be supplied to each Depot. Employer's engineers shall be fully trained to programme, edit and interface the display panels with the system.

Full Details for above mentioned facilities shall be submitted for review by the Engineer. Any other requirement shall be discussed during design stage.

### 13.13 Deliverables

- 13.13.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	13.1.1 (xi)	Complete tools including software, hardware, equipment etc. as per clause 13.1.1 (xi)	One Complete set at each depot.
2.	Deleted.		
3.	13.6.1(v)	The hardware and dedicated software etc. for editing, creating and modifying the speech and route database in line with clause 13.6.1(v).	One Complete set at each depot.
4.	Deleted.		
5.	13.9.2	Any additional tool hardware/software required as per clause 13.9.2	One Complete set at each depot, if required.
6.	13.9.11	Equipment and means for downloading of visual images recorded in non-volatile SSD memory of PSSS.	At least one set of such equipment in each depot.
7.	13.11.3	Adequate tools for modifying/adding etc. the station names as well as audio visual announcements without changing the complete software.	Two sets (as advised by Engineer).
8.	13.12	Set-up facilities for PA, PIS & PSSS in depots as per clause 13.12.	One Complete set at each depot.

#### Note:

- The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
- The cost of these deliverables is deemed to be included in the quoted price of contract.

**14. MATERIAL AND WORKMANSHIP****14.1 General**

- 14.1.1 All equipment shall be constructed in a sufficiently robust manner, and arranged so as not to suffer deterioration, wear, or damage due to vibration or shock loads encountered in traction service.
- 14.1.2 Equipment shall be arranged into groups, where practicable. The items of any one group shall be mounted on a common frame or equivalent, complete with wiring, piping, etc.
- 14.1.3 All such equipment shall be protected against damage caused by dirt, dust, moisture, etc. including during transport.
- 14.1.4 Welding, painting and crimping are considered as special processes. Contractor shall ensure process qualification and validation for these processes and records of the same shall be maintained for scrutiny and review by the Engineer.
- 14.1.5 All relays/MCBs/equipment etc. shall be suitably de-rated for specified temperatures including the proximity effect.

**14.2 Materials**

- 14.2.1 Metals shall be supplied in compliance with the following material standards or equivalent, unless otherwise specified:
- (i) Steel Castings - BS 3100 (grade 592) Latest Version
- (ii) Stainless Steel - chromium content not less than 17%, carbon content not more than 0.03% -JIS 4305 Latest Version.
- (iii) Steel used in welded structures – BS 4360 (WR-50 or WP-50B) Latest Version
- 14.2.2 Glass fiber reinforced plastics may be used for non-structural parts, and applications as accepted by the Engineers. They shall be manufactured to an approved process and satisfy the flammability, toxicity and smoke generation limitations of EN 45545 Part 1 to 7 latest editions, or the better equivalent internationally accepted standard. See also Clause 2.5.8.
- 14.2.3 Synthetic rubber, conforming to International Standards, shall be used for components exposed to sunlight or lubricants during Operation & Maintenance. Complete purchase technical specifications with drawings of all rubber components shall be submitted.
- 14.2.4 Soft metals subject to creep (aluminium, zinc, etc.), shall not be used in applications requiring them to carry current, stress or operate in high temperatures. In exceptional cases, such applications shall be submitted to the Engineers for review.
- 14.2.5 Where copper components require to be annealed or brazed during manufacture, special precautions shall be taken to obviate hydrogen embrittlement.

**14.3 Welding**

- 14.3.1 All welding procedures shall be documented by the Contractor for each sub and major assemblies. Approval of the welding procedure shall be as required by BS EN 288-3: Specification of Approval Testing of Welding Procedures, or equivalent. All welding procedure shall be proven to avoid /control distortion of sub and major assemblies.
- 14.3.2 Approval of the welder shall be as required by BS EN 287-1: Specification for Approval Testing of Welders Working to Approved Welding Procedures, or equivalent.
- 14.3.3 Arc welding shall be performed by the MIG/TIG process and in all cases complete and adequate fusion with the base material shall be ensured. All consumables for welding like gas, electrode shall conform to International Standards. The welding symbols shall be as per ISO 4553 or any other relevant International Standards.
- 14.3.4 The Contractor shall provide details of all preparatory and post-welding procedures to be undertaken during the process of spot welding. Spot welding of components which carry structural loads shall be performed using equipment fitted with time, current and pressure control.
- 14.3.5 The Engineers or Inspector reserves the right to verify the quality of the technique/technology employed for joining the modular element of shell.
- 14.3.6 Deleted.



**14.4 Corrosion**

- 14.4.1 Protection of materials against all types of corrosion shall be appropriate for the environment of Mumbai and the operating conditions of the cars.
- 14.4.2 Corrosion protection methods for metallic components and equipment cases shall be submitted. Where feasible, such corrosion protection measures shall not require to be repeated throughout the life of the vehicle.
- 14.4.3 The Contractor shall take adequate precautions at each stage of processing of stainless steel materials to avoid contamination from harmful materials which can affect corrosion and/or rust resistance properties. Precautions shall also be taken to avoid deep rolling marks, which can potentially affect corrosion resistance properties or enhance stress.
- 14.4.4 The Contractor shall provide suitable protection to eliminate galvanic corrosion, between dissimilar metals.
- 14.4.5 It has been experienced that the un-protected silver contacts/connections get corroded leading to premature failures. Contractor shall take adequate protection during design, selection of equipment & manufacture.
- 14.4.6 Solutions to all corrosion problems, if any, shall be without increasing maintenance activities. Contractor to provide inbuilt corrosion resistant measures over the entire committed life span of the vehicle

**14.5 Fasteners**

- 14.5.1 Screw threads shall be of ISO metric sizes.
- 14.5.2 ISO Metric fine threads shall be used in applications where the fastener is subjected to alternating transverse loads. In other cases, the coarse series of threads shall generally be used, except where precluded by size. The use of studs shall be avoided wherever possible.
- 14.5.3 Normally, screw threads smaller than M5 size shall not be used. Screw and bolt heads shall be of hexagonal form on all M5 and larger screws. Screws smaller than M10 shall be of high tensile material.
- 14.5.4 Fixings shall be locked adequately to prevent loosening in service. Fixings shall withstand any shock loads the equipment is likely to encounter.
- 14.5.5 In critical areas the locking of all nuts, bolts and fixings shall be of a positive form, which prevents mechanical rotation of the nut relative to the bolt, irrespective of source vibration.
- 14.5.6 Stainless steel parts shall be attached by stainless steel screws or fasteners except in locations where high tensile strength is needed.
- 14.5.7 Whenever possible tapped holes shall be drilled and tapped to the full thickness of the material. Blind holes shall be used only where this is unavoidable. All such blind holes shall provide at least 3mm clearance between the end of the screws and the bottom of the tapped hole.
- 14.5.8 Tapped holes shall be provided with suitable thread inserts where necessary, and shall always be used in aluminium or copper.
- 14.5.9 The use of loose nuts and bolts will only be accepted where it is possible for staff to easily reach both parts of the fixing simultaneously.
- 14.5.10 Fixings for covers which may have to be removed for maintenance, shall be captive.
- 14.5.11 Items of electrical equipment shall be fitted to panels so that all fixings can be made from the front only, except where specified otherwise.
- 14.5.12 All steel fasteners used in electrical equipment and/or exterior applications shall be of stainless steel, hot dip galvanised or cadmium plated.
- 14.5.13 Nord lock or equivalent arrangement shall be provided on the fasteners which are subject to heavy vibrations or can cause operational issues.

**14.6 Enclosures**

- 14.6.1 Wherever required equipment shall be mounted in sealed enclosures. Where this is not possible and cooling is essential, the enclosure shall be pressure ventilated using filtered, clean air. Such enclosures may be treated as mounted in clean conditions, as specified in IEC 60077:

Specification for Electric Traction Equipment, or equivalent.

- 14.6.2 Filters shall be of the dry type and shall preferably not require cleaning more frequently than at three monthly intervals. Cleaning shall preferably be by suction cleaning, knocking or blowing off dirt from the filter. If washing of the filters is required this shall be no more frequently than six months.
- 14.6.3 An exception to the above requirement applies only to the vehicle HVAC unit filters, which will be unit replaced for cleaning at two weekly intervals.
- 14.6.4 Air inlets, outlets and vents shall be designed so that ingress of rain, dust or rubbish is prevented, irrespective of whether the car is moving or stationary, and independent of the direction of the wind or the car movement.
- 14.6.5 Enclosure doors and covers shall be securely attached, and wherever possible with quick release latches. These shall include safety devices and keyed access to prevent accidental unlatching.
- 14.6.6 Enclosure interiors shall have smooth easily cleaned self coloured surfaces to assist in maintenance.
- 14.6.7 Apparatus using two stages of insulation shall also be enclosed completely, either in an earthed metal case or in a case made from insulating material.
- 14.6.8 Enclosures in which heat or arcs may be generated shall be lined with barriers of insulating material.
- 14.6.9 All enclosure covers shall be designed to be handled by one person in an ergonomic manner.
- 14.6.10 Signage shall be provided at appropriate positions for clear indication and warning of the potential hazards relating to the equipment or component inside enclosures.
- 14.6.11 The enclosures containing control equipment including relays etc. shall be fully protected against dust ingress and shall be tested for the same.
- 14.6.12 Enclosures/cubicles shall be provided with Linear Heat Detectors (LHD) or heat detectors (refer ERTS clause 2.20) to protect against any abnormal increase of temperature within the enclosed cubicles which may lead to risk of fire.

#### 14.7 Wiring and Cabling

- 14.7.1 All cables and pipes shall be cleated at frequent intervals to avoid vibration leading to abrasion or fracture. All holes through which cables pass shall be fluted, or bushed, to prevent chafing and damage to insulation.
- 14.7.2 High and low voltage cables shall, wherever possible be kept separate. Where cables carrying voltages of greater than 200V between conductors are carried in the same jumper as other cables, they shall be run together only as far as the nearest junction box. Any such arrangement shall be submitted to the Engineer for review.
- 14.7.3 All cable runs in exposed locations, such as on the bogies or underframe and therefore potentially vulnerable to damage shall be in conduits of stainless steel. Where such exposure is not a problem, cables shall be run in enclosed waterproof and dust-proof ducting.
- 14.7.4 All cables of voltage less than 50V shall be kept separated from high and low voltage cables.
- 14.7.5 Wherever cables carrying heavy current, e.g. in traction circuits, pass close to metal structures, adequate clearances shall be provided to obviate inductive heating of the structural members. Temperature rises in the adjacent steel structure shall not exceed 5°C in the steady state condition, with all cables in the vicinity carrying normal working current. Such temperature rise shall be taken into account in selecting the cable ratings.
- 14.7.6 It shall not be necessary to remove cables from their cleats to gain access to equipment for inspection or maintenance. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.7.7 The minimum bend radius in cables shall not be less than twice that required in breakdown tests used in the applicable cable standards. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.7.8 The minimum cross sectional area of auxiliary power cables for connections between equipment shall be 1.5mm<sup>2</sup> copper. External sockets to such cables shall be suitable for 1.5mm<sup>2</sup> copper cables. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.



- 14.7.9 All cables used in the train shall be e-beam cables conforming to international standards (EN/IEC) suitable for being used in underground metros.

#### 14.8 Terminals and Cable Termination

- 14.8.1 Except for electronic equipment, all cable terminations shall be of the crimped type in accordance with BS 4579: Part 1: 1988, Compression Joints in Copper Conductors, or other service proven type. Soldered connections will not be accepted.
- 14.8.2 Crimping standards shall conform to current international practice. The Contractor shall employ only approved and certified staff for crimping process. The Engineer may require that crimped lugs be subjected to random testing before acceptance.
- 14.8.3 Bolted terminations for all high voltage and return cables shall be torque loaded to a defined torque value.
- 14.8.4 Low voltage cables up to 6.0 mm<sup>2</sup> conductor cross sectional area shall preferably be fitted with terminals conforming to BS4579 Pt.1 or equivalent. Alternatives shall be submitted for review.
- 14.8.5 High voltage cables, of conductor sizes up to 6.0 mm<sup>2</sup> shall be crimped using a lug which grips both the insulation and the conductor. An alternative suitable arrangement intended to prevent excessive flexing of the core where it emerges from the lug may be offered.
- 14.8.6 Terminals shall be of the steel screwed post type, securely moulded into an insulation base. All power terminations on one stud shall be assembled together without the use of intervening nuts, washers etc. Studs or bolts shall not be used to carry current. Alternative types of terminal may be offered but their acceptance will be subject to review by the Engineer in design stage.
- 14.8.7 Control cable terminations assembled on one stud in pre-wired removable enclosures shall be separated such that all outgoing connections may be removed without disturbing internal connections.
- 14.8.8 Terminals and terminal boxes shall be so arranged that if water collects in ducts and conduits this cannot reach live components or parts. Measures shall be taken to avoid the accumulation of water in such enclosures.
- 14.8.9 Terminals for circuits of different voltage shall be arranged in separate groups. Negative and neutral terminals shall also be grouped separately. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.8.10 All equipment enclosures and shock mounted equipment shall be grounded using flexible 'strap' type, grounding leads bolted to a designated carbody grounding pad. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.8.11 Alternative terminations may be offered for review by the Engineer.
- 14.8.12 All cable sockets and busbar contact faces shall be tinned. In printed circuit boards contact faces of connectors shall be gold plated. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.8.13 All Cable glands used in cable layout shall be got approved from Engineer and shall be state of art, easily adjustable and fit for long life. The gland shall be flexible and shall have provision to adjust with the cable dia and space available. Use of putty etc. shall not be permissible.

#### 14.9 Electrical Creepage and Clearance

- 14.9.1 Surface creepage and clearance distances between voltage potentials and carbody earth shall be as defined in IEC 60077 Specification for Electric Traction Equipment, for all electrical circuits, equipment and associated cabling. Voltages less than 250V shall be treated as 250V.
- 14.9.2 Creepage or clearance where arcs are present, or along the outside or clearance where arcs are present, or along the outside of a cable sheath, shall be 200% of that defined in IEC 60077: Specification for Electric Traction Equipment. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.9.3 Terminal boards and panel surfaces between terminals and live posts shall as far as possible be vertical to minimise the buildup of tracking paths.

#### 14.10 Protection & Earthing

- 14.10.1 Except as specifically required otherwise, DC and single-phase AC circuits shall be such that one pole of each device shall be connected directly to the negative or neutral line, i.e. without switches,



fuses or contacts on the negative or earthy side.

- 14.10.2 High voltage traction circuits shall be protected in accordance with the requirements of IEC 60077: Rules for Electric Traction Equipment, by an approved fault-interrupting device.
- 14.10.3 In all cases, the fault discriminating characteristics of the system shall be submitted for review.
- 14.10.4 Low voltage fuses and associated fuse carriers shall comply with IEC 60269-1: Low Voltage Fuses. Protection and isolation of low voltage circuits shall be in accordance with IEC 60947-2: Low Voltage Switch Gear and Control Gear: Pt.2 Circuit Breakers or approved equivalent.
- 14.10.5 Grounding connections shall be made through copper or bronze pads of adequate area, to the carbody. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.10.6 High voltage circuits and low voltage circuits should not be earthed together and separate earthing shall be arranged. All earthing pads shall be readily visible and accessible for inspection and trouble-shooting.
- 14.10.7 The Contractor shall produce a complete earthing scheme, which shall prevent traction return current passing through motor and axle bearings, gearboxes, bogie centre bearings, couplers, or any path other than the designed path. The earthing scheme shall be submitted to the Engineer for review.
- 14.10.8 Miniature circuit breakers (MCB's) shall be used only for the protection and isolation of the DC control voltage and AC auxiliary circuits. MCB's shall be of a robust design suitable for use in the railway environment as detailed in IEC 61133.
- 14.10.9 All grounding and bonding jumpers and straps shall either be with copper cables or copper braids of adequate size to handle fault currents and lightning discharge currents, for which the voltage drop shall not exceed 25V. All earthing connections shall be color coded as per relevant International Standards.
- The bonding method employed shall not produce a DC resistance in excess of 0.0025Ω; or more than 0.025Ω at 150kHz for any applied AC voltage.
- 14.10.10 Electrical equipment like capacitors and transformers which can develop internal faults shall be provided with effective devices to isolate at once the defective equipment from the source of power such that there is no fire or explosion at any time.
- 14.10.11 Liquid di-electric materials used in capacitors, transformers and similar equipment shall be of the non-inflammable type.

#### 14.11 Circuit Design

- 14.11.1 Circuit diagrams shall be clear and easy to interpret, and shall comply with IEC 60617-1 to 13 as applicable.
- 14.11.2 Apparatus coding, and cable and wire designations shall be submitted to the Engineer.
- 14.11.3 The soft version of all Circuit diagrams & TCMS sheets shall be inter-linked for smooth and seamless tracing of signals and wiring.

#### 14.12 Electronic Equipment

- 14.12.1 Following type test shall be carried out on electronics equipment used in the train. As a minimum, all electronic equipment shall comply with IEC 60571/EN 50155: Electronic Equipment used on Rail Vehicles, for design, manufacture and testing, and shall use components purchased against an internationally recognised quality assurance and reliability certification procedure.
- (i) Dry heat test: The dry heat test shall be conducted for class T3 and temperature shall be considered 80°C against 70°C specified in IEC/EN. An extra performance check at 95°C shall also be carried out for 10 minutes over temperature value. LCD/LED display units may be tested into 70°C and an extra performance check at 85°C shall also be carried out for 10 minutes over temperature value.
- (ii) Salt Mist test (ST3 category)
- (a) Cyclic Humidity tests (IEC 60571).
- (b) Dust and sand test & Mould growth tests: The tests shall be done as per IEC 60068 & IEC 60721. The dust settlement rate shall be taken as 6gm/m<sup>2</sup>/day and dust particle size shall not be larger than 100 microns.
- 14.12.2 Variable resistors shall be avoided wherever possible.



- 14.12.3 Circuit boards in safety control systems shall be connected through a safety circuit to disable the train if a circuit board is removed, unless the control system is proven safe and tolerant of such circumstances.
- 14.12.4 Electronic components shall only be purchased from suppliers having as a minimum, ISO 9001/2 certification.
- 14.12.5 Electronic equipment shall not be damaged, nor shall malfunction when subjected to direct spikes and surges on the supply and indirect burst transients as defined in IEC 60571: Electronic Equipment used on Rail Vehicles.
- 14.12.6 The Contractor shall furnish the following information in respect of printed circuit boards as a part of contract:
- (i) Voltage and/or waveform expected at each critical test point.
  - (ii) Instructions for carrying out testing and troubleshooting and the function of each circuit block.
  - (iii) Component layout of the printed circuit boards and assemblies.
  - (iv) Connection or interfacing diagrams for the printed circuit boards and assemblies.

#### 14.13 Microprocessors and Software-based Equipment

- 14.13.1 Where microprocessor systems incorporate technology such as surface mounted components, multi-layer circuit boards, or flexible PCBs, the Contractor shall demonstrate that he has operational experience of the successful use of these technologies in a similar Metro environment.
- 14.13.2 All microprocessor based systems shall have watchdog circuits to ensure correct software operation. When the watchdog circuit detects a fault, it shall trigger hardware forcing all system outputs into a safe state before resetting the system and entering a self-test mode. Normal operation shall only be resumed if all self-test checks are satisfactory.
- 14.13.3 Microprocessor systems shall incorporate self-test and diagnostic facilities to locate and indicate faults within the system. The system shall have sufficient built-in diagnostic capabilities to automatically identify all system faults.
- 14.13.4 Where microprocessor electronics systems require additional test equipment this shall be portable for use on the car.
- 14.13.5 LED's shall be used to indicate faulty modules, to allow rapid fault diagnosis and maintenance.
- 14.13.6 Faults occurring during system operation shall be logged, the information being stored in a non-volatile memory.
- 14.13.7 Microprocessor system hardware block diagrams shall be provided.

#### 14.14 Software

- 14.14.1 Software shall be written in a structured manner and fully documented during all stages of its design and development.
- 14.14.2 This shall meet the requirements of EN 50126-2: Dependability for Guided Transport Systems - Part 2: Safety, EN 50128: Railway Applications: Software for Railway Control and Protection Systems, and EN 50129: Safety-related Electronic Railway Control and Protection Systems. Any deviation from this requirement will be subject to review by Engineer in design stage.
- 14.14.3 The Contractor shall submit his Software Quality Plan for review by the Engineer before work commences on software design. The software quality plan shall clearly state the controls and practices used in the software life cycle from specification through to in-service operation.
- 14.14.4 Independent review, verification and testing, using real and synthetic data, shall be performed at the software module and system level. The Engineer may audit the Contractor against the Software Quality Plan at any stage in the Contract. The Contractor shall ensure that all software is fully de-bugged prior to final review by the Engineer.
- 14.14.5 Sufficient software documentation shall be provided to give the Engineer a full understanding of the software function and operation. Documentation shall be complete, yet clear and concise, and include all modifications up to final acceptance. Documentation shall include software block diagrams showing signal flow, logic, and hardware interfaces. A top level flow diagram and description of detailed operation shall be provided.

#### 14.15 Printed Circuit Board and Connectors

- 14.15.1 PCB's of standard design for Rolling Stock applications with components mounted on one/both sides will be acceptable.
- 14.15.2 The minimum thickness of PCB's shall be not less than 1.6mm. PCB's shall generally comply with IEC 60326-3: 1991 Printed Boards – Part 3: Design and Use of Printed Boards.
- 14.15.3 Soldering of electronic components shall comply with the latest internationally accepted practice. Tenderer's shall indicate the standard with which they are compliant.
- 14.15.4 PCB's shall be connected to the case or rack wiring using multi-pin connectors, which shall have a successful service history in rail applications. Details shall be provided.
- 14.15.5 In any electronic rack system, the failure of any one module or individual circuit board shall neither cause loss of the electronics power supply within the rack, nor cause subsequent failure of circuits on other PCB's or modules.
- 14.15.6 Printed circuit board extenders shall be provided for test purposes. The Contractor shall provide detailed maintenance and troubleshooting procedures, including wave-forms at critical locations of the circuitry.
- 14.15.7 PCB's shall have mechanical polarisation to prevent insertion into a wrong socket. The use of PCB edge connectors is not permitted unless reviewed by the Engineer, on a case-by-case basis. PCB's and modules shall be positively retained in the rack or case by a fastener or spring loaded locking pin.
- 14.15.8 All vital and important PCB contact faces of connectors shall be gold plated. The details shall be furnished during detailed design stage.
- 14.15.9 PCB's shall be held in place by screwed fasteners to prevent vibration causing wear on terminal contacts. Circuit boards shall be mounted vertically to minimise the accumulation of dust on the boards. Any deviation from this requirement in exceptional cases will be subject to review by Engineer in design stage.
- 14.15.10 All PCBs shall be adequately lacquered to isolate from environment pollution.

#### 14.16 Integrated Circuits

- 14.16.1 All integrated circuits and semiconductor devices shall be standard devices.
- 14.16.2 All integrated circuits shall be burned in and screened for defects to a level equivalent to relevant international standards.

#### 14.17 Labels

- 14.17.1 All items shall be labelled in English with the maker's name and the type and form of the piece or item, discrete serial number and rating data, and the date of manufacture of the particular piece of equipment. It is desirable that the labels used for different equipment/ sub-systems / systems on the train are of a standard pattern.
- 14.17.2 Rotating machines shall carry a rating plate indicating current and voltage ratings and speed at rated current and maximum speed. In addition, a connection diagram shall be provided inside or adjacent to the terminal box wherever provided.
- 14.17.3 Unidirectional rotating machines shall carry an arrow showing the correct direction of rotation, and in the case of axial fans, of the airflow.
- 14.17.4 The labels shall be clearly stamped, cast or engraved and securely attached to the equipment. Where appropriate, equipment shall be labelled with warnings of high temperature and electric shock risk. Warning labels shall be multilingual (regional language(s) and English and/or Hindi).
- 14.17.5 All cables and busbars shall be provided with durable and legible cable identification markers at each end, corresponding exactly with those on circuit diagrams.
- 14.17.6 Labelling scheme shall be got approved from the Engineer.
- 14.17.7 All cables and busbars shall be provided with durable and legible cable identification markers at each end, corresponding exactly with those on circuit diagrams. The cable identification numbers should remain intact for the entire service life of cable.

#### 14.18 Lubricants

- 14.18.1 The Contractor is expected to utilize, as far as possible, lubricants manufactured in India. With this in mind, he shall furnish a list of grades of lubricants and greases manufactured or available in India, which are considered equivalent to those used by him. The technical particulars of the



Rolling Stock Contractor's lubricants (from the manufacturer's country of origin) shall be furnished to the Engineer.

#### 14.19 Painting

- 14.19.1 All painting processes shall be proven in railway applications, and suitable for the climate of this project, and shall be subject to review. Such processes shall include surface preparation suitable for the material, corrosion preventative priming and high durability finish. Exterior stainless steel, aluminium or their alloys shall not be painted. Bogies shall be treated with primer and an internationally accepted painting system. All steel which will be hidden, except stainless steel, shall be treated with primer and an accepted rust preventative before being concealed. The treatment of copper bearing structural steel shall be subject to acceptance by the Engineer.
- 14.19.2 Employer expects painting of the equipment/ sub-assemblies as per best International practices. Contractor shall submit the guaranteed life cycles for the paint application for different equipment and sub-assemblies for Engineer's review during design stage.

#### 14.20 Rubber Items

All rubber hoses, connecting pipes etc. used in pneumatic circuit shall not be required to be replaced before 5 years or major overhaul whichever ever later. The rubber/ rubber- metal components used in suspensions shall not be replaced before 12 years or during major overhaul of the equipment, whichever is later. All rubber hoses shall be steel reinforced for better life and reliability.

#### 14.21 Cables and Pipes Entries Seal

To prevent entry and ensure fool proof protection against water, dust, humidity, insulation damage/ failure, fire, vibrations, temperature variations, pull tension noise as well as rodents etc. and increasing life of cable/ equipment, all the cables and pipe transits in all cars including rooftop shall be sealed with a suitable EPDM (Ethylene Propylene Diene Monomer) based cable and pipe sealing system. Sealing and Protection application area shall be identified and got approved from Engineer during design stage.

Suitable cable transit system with EPDM should be used for holding/ retention of running power cables and control cables, HT cables at underframe.

**15. INSPECTIONS, TESTS AND TRIALS****15.1 General**

- 15.1.1 Individual cars and complete trains shall be type and routine tested in accordance with IEC 61133, and as specified below. Such tests may be performed either at the Contractor's works, or on site, as appropriate, and as agreed with the Engineer.
- 15.1.2 The individual equipment, systems and sub-systems, shall be type- and routine-tested in accordance with detailed respective test procedures to be drawn up by Contractor and agreed by the Employer which shall take into account the requirements of respective IEC Publications or other appropriate international standards listed in Appendix 'TA', special tests specified in this Chapter, and tests programme drawn up by the Contractor to demonstrate that the individual equipment, sub-systems and systems meet the other specified requirements and agreed by the Engineer. Type test specifications shall be got approved from the Engineer.
- In addition to 'mandatory' tests as prescribed in IECs, the Engineer may also require any of the prescribed 'optional' tests to be carried out.
- 15.1.3 All such tests shall be carried out at the Contractor's cost, wherever performed, in the presence of and to the satisfaction of the Engineer, who reserves the right to witness any or all of the tests.
- 15.1.4 Wherever any equipment, system or sub-system is not specifically covered by an internationally recognised specification or test procedure, or where the type and routine tests prescribed by IEC or other international standard do not adequately cover the requirement, tests which are acceptable both to the Contractor and to the Engineer, shall be devised.
- 15.1.5 Type tests for certain equipment may be waived if these were carried out earlier on equipment of identical design, witnessed by a reputed organisation, and the service performance of such equipment was found to be reliable. The Contractor shall submit a proposal in this regard to the Engineer for review. The waiver of Type Test is entirely at the discretion of the Engineer. Change of manufacturing place may require re-type test.
- 15.1.6 Without prejudice to any other provisions of the Contract, the Engineer reserves the right to witness any or all of the tests, and to require submission of any or all test specifications and reports. The Engineer reserves the right to reasonably call for additional tests as are considered necessary, including the quality of welds particularly in highly stressed areas, by nondestructive testing methods. Prototype tests may be required to verify the suitability of the process or the materials proposed. Engineer may if considered necessary may call for conducting optional tests as per relevant standards without any additional cost to the Employer. In case of repetition of tests, as decided by engineer, entire cost including that of engineer's representative(s) shall be borne by the contractor.
- 15.1.7 The results of all tests shall be submitted to the Engineer, who will record his conclusions as to whether or not the equipment being tested has passed satisfactorily.
- 15.1.8 Certain vital type tests as listed at 15.29 may be witnessed by the Engineer/employer or his representatives. However, the Engineer at his discretion may witness any other tests/FAIs. The contractor shall advise the engineer complete type test plan and seek approval of type test specifications.

**15.2 Inspections**

- 15.2.1 All the materials, fittings, equipment, manufacturing processes, and assembly workmanship shall be inspected by the Contractor, without exception and record for the same shall be maintained and made available for review/check by Engineer.
- 15.2.2 The Employer and the Engineer shall have free access to the Contractor's and sub-contractors' premises, and to any other places where tests are proposed to be carried out, throughout the contract, for the purpose of reviewing and inspecting the designs and manufacturing processes, and mock-ups. The Contractor shall provide the Engineer full opportunity to inspect, examine, measure, and test any of the Works on site, or wherever carried out.
- 15.2.3 The Employer and the Engineer shall be at liberty to inspect the manufacturing process at any stage. Without prejudice to any other provision of the Contract, the Engineer reserves the right to reject all materials and workmanship, which do not fully conform to the specification.
- 15.2.4 Repeated rejections, at either the Contractor's or sub-contractors' facilities, shall be cause for the Engineer to suspend inspection. In such case, the work in question shall also be suspended until satisfactory corrective action is taken by the Contractor.



15.2.5 The Contractor shall not be released from any liability or obligation under the Contract by reason of any such inspection, testing or witnessing, nor by submission of reports of inspection or testing to the Engineer.

### 15.3 Inspection Hold Points

15.3.1 The Contractor shall, propose a set of inspection hold points in the Inspection, Testing and Commissioning Plan. The hold points shall be structured so that a formal hold point is allowed for each significant element of the car's manufacturing process. At each hold point the Inspecting Officer appointed by the Employer shall hold a formal inspection, or advise that the inspection has been waived.

15.3.2 The manufacture of each car or part thereof shall not proceed until the inspection by the Inspecting Officer has been completed or waived.

15.3.3 The Employer and the Engineer shall be afforded the opportunity of inspecting all cars, trains and mock-up to be delivered under the Contract before they leave the Contractor's premises. No car shall be considered ready for delivery without Engineer endorsement in writing.

15.3.4 The Contractor shall advise the Engineer no fewer than 30 days in advance of a car or train being available for inspection, and shall notify him of the tests proposed to be carried out. In case inspection is not carried out at the time agreed upon as a result of the Engineer not being available, the Contractor shall notify the Engineer immediately and he will deploy an Inspecting Officer within one week. In case the Inspecting Officer fails to turn up within this period, the Contractor may proceed with the work and the Inspection Certificate issued by the Manufacturer will be accepted by the Engineer.

15.3.5 Once the inspection and any required remedial actions are completed to the satisfaction of the Engineer, he shall give consent for the cars' or trains' shipment and/or dispatch.

### 15.4 Test Planning & Procedure

15.4.1 The Contractor shall submit detailed test procedures for each of the equipment/sub system/system for the review of the Employer as part of design submissions. The plan test procedures shall include the following information:

- (i) Relevant specification applicable to each of the tests.
- (ii) Type, routine and special tests to be carried out.
- (iii) Description of the tests, scheduled dates, and locations of the tests.
- (iv) Test parameters to be measured.
- (v) Constraints to be applied during the test.
- (vi) Defined pass/fail criteria
- (vii) Facilities, equipment, and test and measurement tools.

Test procedures shall be amended, as required by the Contractor throughout the duration of the Contract, to reflect changes in system design or the identification of additional testing requirements.

15.4.2 The Engineer shall have the facility to monitor all tests and have access to all test records. Ample time shall be allowed within the testing programme for necessary alterations to equipment, systems and designs to be undertaken, together with re-testing prior to final Commissioning.

15.4.3 Unless agreed in writing by the Engineer, personnel engaged on testing shall be independent of those directly engaged in the design or installation of that equipment.

15.4.4 All test equipment shall carry an appropriate and valid calibration label and / or certificate.

15.4.5 For each of the identified tests, the Contractor shall produce a test report, in three copies, and in an approved format, within an agreed period following the test, for acceptance by the Engineer. The Contractor shall sign all reports of Tests. The Employer reserves the right to reasonably call for additional tests if considered necessary.

### 15.5 Obligatory Tests on Prototype

15.5.1 For introduction of a Rolling stock in revenue service, tests are required to confirm that the design meets all the specified safety and statutory requirements and the train is fit for revenue service. Present statutory requirements make it mandatory to follow the Research Design & Standards

Organization (RDSO) "Procedure for Safety Certification and Technical clearance of Metro systems" for introducing new rolling stock for passenger services and "The Metro Railways General Rules". A copy of the same is attached in Part-II: Section 6G. The methodology & acceptance criterion for conducting oscillation trials as mentioned in the above RDSO procedure Annexure- F-1 & F-2 (latest updated) shall be applicable.

- 15.5.2 As per statutory requirements in India the passenger cars have to fulfill the following requirements "under all conditions of track upto maintenance limits" (table 15.1 'A') at all speeds.

Table 15.1 'A' Obligatory requirements on prototype

S. N.	Term	Conditions	Acceptable Value
1.	Maximum vertical Acceleration on coach body	Measured on car floor of car body as near to bogie center as possible	$\leq 0.27$ g
2.	Maximum lateral Acceleration on coach body	Measured on car floor of car body as near to bogie center as possible	$\leq 0.27$ g
3.	Maximum Dynamic wheel unloading $\Delta Q/Q$	-----	$\leq 0.5$
4.	Maximum value of RI	Calculated on the basis of acceleration values recorded in items (1 and 2) above	3.0 for both vertical & Lateral directions
5.	A general indication of stable running characteristics of the vehicle as evidenced by the movement of the bogie on a straight and curved track and by the acceleration readings and instantaneous wheel load variation.		

The oscillation trial are to be conducted with tare and fully loaded vehicles, in both inflated and deflated conditions upto maximum designed speed starting from 40 kmph in the incremental order of 10 kmph; upto 90 kmph .

As far as operation with deflated springs are concerned, trials will be conducted upto the speed where the above maximum level of parameters are experienced and based upon the results, the maximum speed of operation with deflated springs will be decided.

The test will preferably be conducted on track blocks of approximately 200 m each for tangent track and 100m minimum for curve track. The minimum total numbers of blocks will be 25. However the actual test scheme shall be decided based on the section available for testing. The results will be calculated for each block separately. The maximum value of each index on the results of evaluation of all blocks independently will be the accepting criteria. The oscillation trials may have to conducted in stages to facilitate opening of section. Contractor shall plan accordingly.

The contractor shall also make arrangements to measure the forces / impact on the check rails on main line / turn outs with new and wornout wheels. Suitable interface shall be ensured with the track contractor. The forces, if any, shall bewell within limits .

The performance of each type of car will be separately evaluated.

- 15.5.3 Besides the above statutory test, other tests as specified in EN14363 including following investigation test to confirm the safe behaviour of the coach will also be carried out
- Measurement of natural frequency in Bouncing, pitching and
  - Rolling modes using a wedge of 18mm (Investigation test)
  - Bogie Rotational resistance (x-factor)
  - Damping Factors.



- (v) Braking Distance Test.  
 (vi) Carbody movements with reference to the KE

Table 15.1 B – The Limiting Values

S.No.	Term	Conditions	Acceptable Value
1.	Damping factor (under tare condition)		
	(i) Lateral	By quick release side pull test	0.30 to 0.40
	(ii) Vertical	Using wedge of 18 mm thickness	0.20 to 0.25
2.	Bogie Rotational Resistance	Under tare with inflated & deflated spring conditions	< 0.08 at 0.8 degrees per second rotational speed
3.	Emergency Braking Distance of 6 car train set with all bogie brakes working under fully loaded conditions.	Pick up speed of 80 kmph on level tangent track & apply emergency brakes	245m (Maximum)

## 15.5.4

- (i) Employer intends to appoint an independent and authorized certifier of Rolling Stock to supervise the trials and certifying the fitment of cars for inductions in revenue service.  
 (ii) The instrumentation requirements and the manner of conducting the test etc will be decided by authorized certifier jointly with the contractor and approved by the Engineer. The Contractor shall provide full instrumentation for this purpose.  
 (iii) Engineer will also witness the trial.

15.5.5 Software package required for analysis of the raw data acquired during oscillation trials shall be supplied by the Contractor at designated Depot as advised by the Engineer. The cost of this software package is deemed to be included in the quoted price of contract. Necessary training to use this software package shall also be given to the Engineer's Representatives.

## 15.6 Integrated Testing and Commissioning

15.6.1 Complete propulsion system shall be tested on Combined Test Bed as per IEC61377. On completion of testing and commissioning of the Contractor's own system to the satisfaction of the Engineer, the Contractor shall carry out all tests necessary to verify the functioning of his system with those of other Designated Contractors. These tests shall be carried out in various phases and for different sections, as the work progresses. Following procedure shall be adopted:

- (i) Complete propulsion system incl. Transformer, converter-inverter, traction motor with loading arrangement shall be placed on test bed. Preferably arrangement shall be made to heat the ambient air to 47°C during the tests. It will be preferred to use the same gear case & transmission arrangement as proposed during design.  
 (ii) List of points where temperature shall be measured shall be finalized with the Engineer. Decision of engineer shall be final and binding.  
 (iii) All specified operational scenarios shall be tested. These include emergency cases also.  
 (iv) Worst case conditions with permissible wheel dia difference of 8mm  
 (v) 6 car train (with 1MC isolation) pushing 6 car train on 4% gradient shall also be included as one of the investigative case.  
 (vi) Performance test shall be done at half worn wheel. Suitable correction shall be made for traction motor temperature under full wheel dia.  
 (vii) The parameters recorded during combined test bed shall be revalidated during line tests as per IEC

1133. The recorded values during line test shall be normalized by adding the difference of temperature rise due to wheel dia difference as above, difference due to measurement procedure adopted in field and specified in IEC 60349 (Winding resistance method) and difference in ambient temperature from the specified. Similar normalization shall be done for other equipment as well.

- (viii) Train Performance test (IEC 1133): Compete train shall be subjected to the tests specified in IEC 1133 or any other tests required to be incorporated by the engineer. Detail test protocol shall be drawn and got approved from the engineer. The train performance specified in ERTS3.22 shall also be got validated along with the final simulated performance parameters after design. The run time performance shall meet the following parameter.

Train Load (1)	Achieved Speed (KMPH) (2)	Minimum Distance Moved (m) in time at Column (4) (3)	Maximum Time taken to achieve the speed (sec) (4)
Crush load @ 8 passengers/m <sup>2</sup> and All out run	0 to 40	62	12
	0 to 60	232	23
	0 to 80	811	53
Crush load @ 6 passengers/m <sup>2</sup> and All out run	0 to 35	40	9
	0 to 60	213	21
	0 to 80	715	47

The measurements shall include jerk consideration and shall start from the moment the Master controller is brought to traction. The measurements shall also be done during ATO and shall be optimized. Similar procedure shall be used for testing of regenerative braking.

- 15.6.2 Tests and test procedures shall be submitted by the Contractor for acceptance by the Engineer or as required by him.
- 15.6.3 The Integrated test procedures shall include, but not limited to, the necessary tests to verify the functioning with the Designated Contractors responsible for the following systems:
- (i) Signalling and Train Control
  - (ii) Telecommunication
  - (iii) Overhead Equipment
  - (iv) Civil Constructions for underground sections
  - (v) Track works
  - (vi) Station Construction
  - (vii) Depot Equipment Supply
  - (viii) Platform Screen Door (PSD)
  - (ix) Any other Designated Contractor as communicated by the Engineer.
- 15.6.4 All defects and shortfalls in the Contractor's system, discovered in the course of Integrated Testing and Commissioning, shall be made good and re-tested to the satisfaction of the Engineer before the commencement of service trials.
- 15.6.5 On completion of the Integrated testing and Commissioning, to the satisfaction of the Engineer the Contractor shall confirm in writing to the Engineer that the rolling stock provided by him is suitable for the purpose of service trials.



**15.7 Service Trials**

- 15.7.1 The prototype and other trains shall be subjected to pre-revenue Service Trials. Service trials are intended to prove not only the satisfactory running performance of the cars, but also to enable practical evaluation of their reliability in service, ease of maintenance and operation, in parallel with the work of other Designated Contractors, and adequacy of the cars and equipment for all performance requirements envisaged in the specification.
- 15.7.2 Service Trials for the prototype train shall be carried out for a minimum of 2,000 km and for other trains 500 km which may be further subjected to Engineer's review during design stage.
- 15.7.3 The Contractor shall submit the Service Trial Procedure for review by the Employer, enlisting the various operability and maintainability aspects to be performed during the service trials.
- 15.7.4 During the Service Trial period, the Contractor shall make the train set completely fit for introduction in revenue service.
- 15.7.5 The Contractor shall make all necessary arrangements including temporary provisions in his system to ensure safety during service trial period. The Contractor shall provide full support by way of driving Instructors, staff and material during the Service Trials of the prototype and first few (maximum 10 no) trains. By that time the contractor shall complete on-shore training of train operators and provide competency certificates to such trained TO's, who are found suitable for driving such trains.
- 15.7.6 During the pre-revenue operations, the Contractor and designated contractors, will run trains subject to constraints of the ongoing construction activities.
- 15.7.7 Trains shall be inducted into Revenue Service only after Service Trials to ensure that functions and operations of various systems are satisfactorily integrated and permit all the technical systems to stabilise.
- 15.7.8 Upon completion of Service trials the Contractor shall submit a statement confirming that the rolling stock is safe and ready for commencement of revenue service.

**15.8 Special Tests**

- 15.8.1 The Contractor shall carry out the requisite tests to demonstrate the performance of equipment, sub-system and system as per procedure mentioned in clause 15.4. The following clauses specify tests which are either not covered by standard specifications, or require the provisions of the standard specification to be modified to some extent.

**15.9 Vehicle Body Shell**

- 15.9.1 Car body strength test (see clause 4.6) shall be carried out and a lifting test shall also be performed in accordance with UIC 566/EN 12663 (clause 1.2.2.3) under simulated loads as specified, as type test.
- 15.9.2 Crashworthiness shall be proved by submission of detailed calculations and demonstration by means of finite element analysis.
- 15.9.3 The strength of the saloon car side wall windows and of those in the doors shall be performed in accordance with UIC 566/EN 12663, as a type test.
- 15.9.4 The strength of the cab windscreen shall be tested in accordance with the requirements of both UIC 651 and UIC 566/EN 12663, for a maximum train speed of 85 kmph also as a type test.
- 15.9.5 The strength of couplers and draught gear shall be carried out in accordance with international practice, also as a type test.
- 15.9.6 The carbody shall also be subjected to a vertical deflection test. All side doors on one side of the car shall be installed, complete with drive mechanisms, and all sealing and weather-stripping.
- 15.9.7 At each increment of test load the doors shall be opened and closed by means of the door controls. Any failure to operate at the prescribed speed profile, or any indication of binding, shall require corrective action to be taken by the Contractor, to the car structure, to the door arrangement, or both.
- 15.9.8 One shell out of every 4 bare shells, to be randomly selected by the Engineer, shall be subjected to water tightness test as per an agreed procedure based on IEC 61133.

**15.10 Bogie Tests**

- 15.10.1 The bogie frame(s) shall be subject to static as well as fatigue tests in accordance with UIC 515-4



for T car bogie and UIC 615-4 and EN-13749 for DM and M car bogie, with the payload as specified in Chapter 5. This shall be a type test. However, in case of only one type of bogie frame is proposed to be tested, the maximum of all loads shall be considered.

- 15.10.2 Tests for clearances in the bogie, and between bogie and body shall be carried out on straight track as a routine test.
- 15.10.3 Tests for clearances in the bogie, and between bogie and body shall also be carried out by rotating the bogie to simulate a 100m radius curve. This shall be a type test.
- 15.10.4 The Contractor shall perform a wheel-unloading test to verify the calculations submitted. The test shall be conducted in the most disadvantageous combination of unloading and suspension conditions.
- 15.10.5 A load deflection test and accelerated ageing tests shall be performed to demonstrate that the spring rate of the primary suspension system and the creep rate for the materials used are within the design limits.
- 15.10.6 These tests shall prove that the primary suspension system behaves as predicted and will not result in excessive deflection or a decrease in bogie clearance above top of rail to less than the minimum specified herein.

#### 15.11 Passenger Saloon Door, Type Tests

- 15.11.1 The body side doors shall be tested for strength as required in Chapter 7, for relevant parameters which are required to be met.
- 15.11.2 The following type test shall be carried out on a complete double leaf door and operating assembly equipment with its control gear.

(i) Endurance

Two million operations shall be performed. A record of the velocity profile shall be taken at the beginning and the end of the test. It should also be demonstrated that no undue wear or compression of seals has occurred. This test shall be performed under representative dry and wet conditions. Endurance test shall be done on actual replica of the door portion of the car and door shall be as assembled in the coach. Approval of engineer shall be sought on the complete arrangement.

(ii) Vibration Tests

Vibration test shall be carried out as defined in IEC 61373.

- 15.11.3 Detrainment door Endurance test—The door/detrainment arrangement shall not deform after loading and unloading cycles with equivalent load of passengers in 6 car train/8 car train.

#### 15.12 Passenger Saloon Door, Routine Tests

- 15.12.1 These will comprise functional test to verify that performance is consistent with accepted type test results, and shall include tests to IEC 60077 for the electrical portion.

#### 15.13 Saloon to Cab Door Type tests

- 15.13.1 The Prototype Saloon to Cab door shall be subjected to an endurance test of one hundred thousand (100,000) operations, during which it shall be demonstrated that no component fails.

#### 15.14 Compressor and Motor Test

##### 15.14.1 Type Test

(i) Starting Test

The motor shall undergo type- and routine-tests in accordance with IEC 60349-2, Electric Traction. Rotating Electrical Machines for Rail and Road Vehicles, Part 2-Electronic Converter Fed Alternating Current Motors.

The compressor shall undergo type- and routine-tests in accordance with ISO 1217: 1996 and BS 1571: Pt.2: 1984 Methods for Simplified Acceptance Testing of Air Compressors and Exhausters.

In addition to the above, starting tests shall be performed, five times at the maximum permissible rated voltage, and five times at the minimum rated voltage, the ten tests being performed in succession, at two minute intervals, at the specified reservoir pressure. The machine shall not exhibit a temperature rise higher than the specified maximum permissible.



## (ii) Voltage Interruption Test

The supply shall be interrupted and restored, at intervals of one second, five times in succession, allowing the normal load conditions to be re-established between successive interruptions, the motor operating at its maximum voltage and rated load. The motor shall withstand the test without mechanical deterioration.

## (iii) Heat Run

The set shall be tested at its rated voltage against the specified pressure for six hours, to show that the motor temperature rise does not exceed the specified limit, based on the class of insulation, and that the permissible temperature rise of the compressor is not exceeded.

## (iv) Air Quality check of complete unit as ISO procedure.

**15.15 Brake Equipment Type Tests**

15.15.1 Brake system and its components shall be subjected to type tests as per relevant UIC. Following Tests shall be carried out on TBUs based brake system:

- (i) Functional checks such as working stroke, slack adjuster operation and parking brake action.
- (ii) Recording of the relationship of brake pad force to cylinder pressure over the full working range.
- (iii) Plotting of brake force against pressure curves in all conditions of operation of brake cylinder and parking brake.
- (iv) Vibration test as defined in IEC 61373.
- (v) Air leakage test.

## 15.15.2 Brake Lining:

The Contractor shall carry out testing of brake pads in respect of coefficient of friction with respect to the wheel tread under dry and wet conditions, maximum temperature attained during braking, rate of wear etc.

## 15.15.3 Brake Control Equipment

Individual items of electro-pneumatic equipment shall be type tested as follows:

- (i) Mechanical Operation and Endurance as defined in IEC 60077
- (ii) Vibration and Shock as defined in IEC 61373.
- (iii) Air Tightness generally as in IEC 60077.
- (iv) Electrical Test, generally as in IEC 60077.
- (v) Characteristic Tests
- (vi) Each item of equipment having a pilot or transducing function, shall be tested to confirm compliance with the Contractor's design data. Oscillograms shall be produced in support.
- (vii) Type Tests on Electronic Equipment

The electronic equipment used in brake system shall be tested as laid down in IEC 60571 and EN 50121-3-2.

## 15.15.4 WSP test

Complete train (AW0 & AW3) shall be subjected to Wheel slip-slide type test as per UIC 541-05. The detail type test specification shall be got agreed from the Engineer. Followings shall be included in the type test

- (i) Braking Modes as EB (Emergency Brake), FSB (Full Service Brake with ED Dynamic Brake), FSB (Full Service Brake without ED Dynamic Brake) and EB (Emergency Brake) with 1 M car isolated for Evaluation with at least 4 valid runs each.
- (ii) Braking Modes as FSB (Full Service Brake with ED Dynamic Brake) followed by Failure of ED Dynamic Brake, FSB (Full Service Brake with ED Dynamic Brake) followed by EB (Emergency Brake) for Reference with at least 3 valid runs each.



- (iii) Low Speed and Low Adhesion WSP Tests will be done for reference at speeds of 25kmph and initial adhesion < 5%
- (iv) WSP Tests will be done on Randomly selected 3 trains in Tare Load in speed range 60-30kmph for Braking Modes as EB (Emergency Brake), FSB (Full Service Brake with ED Dynamic Brake), FSB (Full Service Brake without ED Dynamic Brake) for evaluation as and when directed by Engineer.
- (v) Initial Adhesion will be evaluated as per UIC i.e. when First axle starts sliding irrespective of location on train. In case of Full Service Brake with Dynamic Brake First axle to slide is expected from Motor car due to Dynamic Brake applied on Motor Car.
- (vi) An Axle will be considered Sliding if its speed is at least 10% lesser than Reference Speed.
- (vii) Minimum Slide Criteria will be fulfilled on the basis of Braked Axles of complete Train Set i.e. At least 50% of braked axles, of train. Axle will be considered Sliding if it is sliding for more than 35% of the time (Actual time taken from 85-45 or 60-30).
- (viii) Extension of Stopping Distance in Wet Condition over Dry Condition, for Adhesion Level of 6-8% will be 15% and 25% for adhesion level of 5% up to 6%.  
Braking Distance under Dry and WSP condition shall be within the distances specified in the Table 15.2.

WSP software shall be fine tuned to ensure minimum reduction of brake distance due to low adhesion and shall be state of art being used in metros worldwide by the contractor.

Table 15.2: Braking Distance under Dry and WSP condition

Braking Mode	Speed (kmph)	Maximum Braking Distances for AW0 and AW3 (meters)		
		DRY	WET (Adhesion)	
			6%-8%	5%-6%
EB	85	245	282	306
	60	123	142	153
EB (1 car Isolated)	85	308	354	385
	60	158	182	198
FSB with ED	85	307	354	384
FSB w/o ED	60	155	179	199

### 15.16 Complete Brake System, Type Tests

15.16.1 A complete set of brake equipment comprising all items of equipment forming the Brake System shall be assembled and shall be subjected to brake system bed test. These shall include the Brake Controller and interface with ATO equipment and a transceiver to measure force at the push rod of Brake unit. A complete series of tests shall be carried out on this rig under all service conditions to demonstrate the function of the brake system as a whole, both in manual and auto modes.

The Contractor may submit a proposal to combine the test of individual items with the system test if agreed by for review and acceptance of the Engineer.

15.16.2 Instrumented tests shall be carried out at train level both in tare and loaded condition, to establish designed performance of pneumatic/ regenerative braking. Similarly, emergency braking distance tests shall be carried out in tare and loaded condition under dry and wet rail conditions. Wheel Slide Protection system shall be tested under dry and wet rail conditions. The Contractor shall submit detailed Test Procedure for review by the Engineer.

15.16.3 The prototype train shall be used for carrying out emergency braking distance trials under tare and loaded conditions of the train.

### 15.17 Complete Brake System, Routine Tests



15.17.1 All reservoirs shall be tested to an appropriate international pressure vessel standard and necessary test certificates shall be provided from a recognised test agency.

#### 15.18 Propulsion System Type Tests

15.18.1 The Contractor shall, in addition to type tests carried out individually on all electrical equipment, in accordance with internationally accepted specifications, shall undertake combined propulsion, braking and TCMS test, using simulated loads on the traction motors. The testing shall reflect, as far as practicable, the layout of equipment on the car. Combined propulsion system testing shall be in accordance with IEC 61287-1 and IEC 61377.

15.18.2 Testing shall include simulated service operation, fault handling, including wheel slip/wheel slide control, braking and load weigh interfaces and abnormal operation and failure condition operation.

#### 15.19 Auxiliary System Type Test

15.19.1 Testing shall be carried out to demonstrate the ability of the auxiliary power system to provide the required level of standby power under the normal and emergency conditions specified in Clause 9.4.

#### 15.20 TCMS Type Test

15.20.1 The Contractor shall perform tests on the TCMS system to verify designed capacity of the systems, proper functioning, robustness, efficiency, ease of use and maintenance for the TCMS software, with reference to the design specification, correct interfaces as described in Chapter 10. The real interface hardware and software should be used where possible. All software parameters, as well as the functionality and reliability of its associated hardware shall be validated on-board a completed train. The test procedure shall be submitted for acceptance by the Engineer, prior to the commencement of the test.

#### 15.21 Roof Mounted HVAC Package Unit Type Tests

15.21.1 The following tests shall be carried out at the manufacture's works or at a reputed testing laboratory on the prototype unit in the presence of the Engineer.

- (i) Refrigerant circuit leakage test (with nitrogen gas under pressure, before filling refrigerant), vacuum test, refrigerant gas charge quantity test and refrigerant gas (right quantity of refrigerant in HVAC unit) and refrigerant leakage tests (less than 3 gm/year leakage). Any leaks shall be corrected and the leakage tests repeated.
- (ii) Dimensional and visual inspection, including weight test.
- (iii) Measurements in Psychrometric Test Rooms

##### (a) Blower fan performance tests

- Fresh air, return air and supply air flow rates shall be measured for different fresh air damper openings. Static pressure developed by the blower fan at the outlet shall be recorded for different supply air flow rates. All supply air flow rate versus pressure graphs shall be plotted to demonstrate blower fan performance. Emergency air flow rate shall also be measured. These measurements may be made with only blower fan(s) working. The test room temperatures need not be controlled.
- Parameters to be measured
  - Fresh air, return air and supply air flow rates;
  - Condenser fans air flow rate;
  - Static pressure at blower outlet.
- Acceptance criteria
  - Supply airflow rate at blower fan outlet static pressure of 25 mm WG should be equal to or more than design supply airflow rate;
  - Design air flow rates should be achieved at different fresh air damper openings.

##### (b) Cooling and heating capacity tests

- These tests shall be conducted by adjusting static head at 25 mm WG at blower fan outlet. The tests shall be conducted as per ASHRAE 37 or IS 8148 or any other acceptable standard in the following conditions of hot and cold rooms when all compressors are working or in case of variable frequency control all compressors should be working at highest frequency:

Table 15.3: HVAC unit test Conditions

Test Condition	Ambient Condition	Car (Inside)
Dry summer condition	36°C 65% R.H.	25°C 60% R.H.
Monsoon Condition	32°C 85% R.H.	25°C 60% R.H.
High ambient	50°C	25°C 60% R.H.
Extreme ambient	58°C	25°C 60% R.H.
Low load	19°C, 60% R.H	25°C 60% R.H.
High humidity	27°C, 90% R.H	25°C 60% R.H.

All the above cooling tests shall be conducted for 3 hours in steady state conditions, except for extreme ambient test at 58°C, which will be conducted for 1 hour in steady state and low load test to be conducted for 4 hours in steady state. More tests can be added by Engineer.

Cooling capacity tests under summer & monsoon ambient conditions will have to be conducted to check COP as per ERTS clause 11.2.14 under all combinations of compressor's operation (i.e. different no. of compressors working & different operating frequency steps in case of variable frequency control pertaining to different loading conditions from AW0 to AW3.

- Parameters to be measured
  - Temperatures and humidity at various locations of the HVAC, hot room and cold room;
  - Fresh air, return air and supply air flow rates;
  - Condenser fans air flow rate;
  - Static pressure at blower outlet;
  - Condensate water drainage rate;
  - Refrigerant temperatures and pressures at different locations;
  - Voltage, current and power factor of compressors, blower fan(s), condenser fans and heaters.
- Calculated values
  - Cooling capacity from evaporator and condenser side;
  - Power consumption in compressors, blower fan(s) and condenser fans;
  - EER or COP;
  - Heating capacity and power consumption in heaters.
- Acceptance criteria
  - Design and ERTS specified cooling capacities and COP to be achieved;
  - There should not be much difference in cooling capacities measured from evaporator side and condenser side;
  - Air flow rates should not change during the tests;
  - The HVAC unit should not trip/stop during the tests;
  - HP and LP switches should not trip during the tests;
  - Ice should not form over evaporator coils;
  - Condensate drainage should be smooth, with no water accumulation in the drain pan;



- Condensed water should not be carried in the air stream to the heater coils, blower fan and supply air discharge plenum/duct/diffusers.

(iv) Insulation Resistance Test

Insulation resistance tests under all weather conditions shall be undertaken on all equipment, using a IR tester suitable for the equipment as specified in the EN/IEC. The resistance reading shall in no case be less than 100MΩ.

(v) Dielectric Test

The equipment shall withstand a high potential difference as specified in the EN/IEC .

## (vi) Voltage change test and frequency change test;

## (vii) Starting sequence test;

## (viii) External and internal smoke tests;

## (ix) HP and LP cut-out tripping test;

## (x) Thermal expansion valve superheat test;

## (xi) Fresh air damper and return air damper tests;

## (xii) Temperature probes test;

## (xiii) Rain/water tightness test;

## (xiv) PLC functional test and software testing;

## (xv) Acoustic test as per ISO 9614-2 and ISO 7626-5, or any other relevant standard;

(xvi) Vibration and Shock Tests

These tests shall be done as per IEC 61373;

(xvii) EMC Test

EMC test shall be carried out in accordance with EN 50121-3-2 on one unit;

(xviii) Testing of Emergency Inverter

The Emergency Inverter unit shall be tested in accordance with IEC 61287, EN 55101 and IEC 61373;

## (xix) All rotating electrical machines shall be tested in accordance with IEC 60349-2: Electric Traction - Rotating Electrical Machines for Rail and Road Vehicles Part 2-Electronic Converter Fed Alternating Current Motors.

**15.22 Complete Car HVAC System Type Tests**

15.22.1 One car body equipped with all interior finish and all underframe mounted equipment, shall be tested to demonstrate the effectiveness of the equipment in meeting the specified temperature and humidity conditions inside the car. Complete car shall be tested in climate conditions as specified in the ERTS, EN 14750 or other relevant standards.

15.22.2 The extent of such tests shall be decided by the Engineer and shall include, as a minimum, the following:

(i) **Air Distribution Tests**

(a) Air velocities and air flow rates shall be measured at all saloon supply air diffusers to ensure even distribution of air along the length of the car for each duct partition. Air velocities should not exceed ERTS and standards limits.

(b) Air velocities in side supply air ducts, at different saloon passenger areas, at return air and exhaust air grilles/ openings shall be measured to check that they do not exceed the ERTS

and standards limits.

(ii) **Air Flow Tests**

- (a) Air velocities and air flow rates will be measured at the fresh air inlets to the HVAC unit, exhaust air openings, inlets to cubicles and return air inlets for different fresh air damper openings for clean and clogged filters and evaporator coils. Emergency ventilation and any other special air flow requirement shall also be measured for verification. Interior static pressure shall be recorded for all conditions. Measured values should satisfy ERTS, relevant standards and design values.
- (b) Condenser fan inlet and outlet airflows shall be measured.

(iii) **Cooling performance test**

- (a) These tests shall be conducted inside a Climate Chamber for judging the cooling and heating performances of the HVAC system for Summer, Monsoon(for under tunnel ventilation), high ambient, low ambient, high humidity and any other ambient conditions as per EN 14750 or any other equivalent standard and Engineer's requirements. Heating and humidifying equipment shall be provided in the car for test purposes. Testing shall be done for different passenger loads for:
- Pre-cooling (with full passenger occupancy heat load) - Set temperature should be achieved in 30 minutes.
  - Regulation (doors closed) - Cooling capacity of HVACs shall be sufficiently high to demonstrate 3 complete regulation cycles during the regulation test.
  - Doors open-close - It should be done for 10 cycles as per EN 14750, and/or for door open-close cycles for complete to-and-fro route run, as decided by the Engineer.

Any other test as required by the Engineer shall also be conducted.

- (b) Measurements of thermal conductivity (K factor) and cooling capacities shall also be done as per EN 14750-2.

(c) **Parameters to be Measured and Criteria**

• Recorded Parameters

Temperature, humidity, pressure, current, voltage, power etc. at various locations of the HVACs, test car, climate chamber and equipment used for creating the ambient and interior heat load conditions. Each parameter shall be recorded on a digital data logger.

• Acceptance Criteria

- (i) ERTS, relevant standards and design values should be achieved.
- (ii) In regulation tests, there should not be large variations in interior conditions.
- (iii) Pre-cooling timings should be less than 30 minutes.
- (iv) HVAC system should be able to quickly recover average interior temperature and humidity within the average doors closed interval and shall maintain this performance indefinitely, without degradation of interior conditions on long runs.

15.22.3 Fresh air flow rate shall also be verified by using dummy passengers as per full passenger load and measuring interior CO<sub>2</sub> levels with doors closed and doors open-close situation in all different types of cars.



15.22.4 TCMS-HVAC interface testing shall be done.

15.22.5 Any other vehicle level tests as deemed necessary by Engineer shall be conducted.

### 15.23 HVAC System Routine Tests

15.23.1 HVAC Unit Routine Tests (to be done on all units)

15.23.1.1 Dimensional & Visual inspection.

15.23.1.2 Refrigerant charging and leakage tests

- (i) Refrigerant circuit leakage test (with nitrogen under pressure),
- (ii) Vacuum test,
- (iii) Refrigerant gas charge,
- (iv) Refrigerant gas leaking tests (less than 3 gm/year leakage).

15.23.1.3 Electrical tests

- (i) Insulation resistance test
- (ii) High voltage test (Dielectric test)
- (iii) Presetting of thermal overload relay.

15.23.1.4 Functional and running tests (to check functioning of working parts and to measure some important performance parameters). These tests shall also include measurement of conditioned air-delivery, fresh air quantity and power consumption.

15.23.1.5 Rain/water tightness tests.

15.23.2 Complete Car HVAC System Routine Tests (to be done on all cars).

15.23.2.1 Preliminary checks and checks before ACU operation.

15.23.2.2 Checks under ACU operation conditions

- (i) System operation start,
- (ii) Airflow checks,
- (iii) Temperature checks,
- (iv) Failure checks using TCMS,
- (v) Emergency ventilation,
- (vi) Functioning of smoke detection units.

### 15.24 Emergency Operation

15.24.1 After delivery of two trains, the ability of one healthy train to rescue a disabled train in section as specified in Clause 3.23 shall be tested.

### 15.25 Noise and Vibration Verification

15.25.1 The Contractor shall perform noise and vibration type tests on complete 6-car trains to demonstrate compliance with Clause 2.18. All test procedures; data and results shall be submitted to the Engineer for acceptance.

### 15.26 Fire Performance Verification

15.26.1 Types tests according to the EN 45545 (part 1 to 7) shall be undertaken to establish fire ratings for all materials proposed. However, test certificates from any Testing Agency of international repute may be accepted in lieu by the Engineer at his sole discretion.

#### 15.26.2 Fire Detection System Functional Tests

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The aim of these tests is to prove functionality and positioning of smoke and heat detectors in passenger areas and heat detectors/LHD in electric cabinets (enclosures/cubicles). The tests shall conform to the requirements of the ARGE Guideline (Part-1 for "Fire detection in Rolling Stock" and Part-3 for "System functionality fire detection & fire fighting in Rolling Stock") or any other applicable international standard.

Type tests shall be conducted for the following:

- (i) Dual Smoke and Heat detectors (multi-sensors),
- (ii) Heat Detectors,
- (iii) Linear Heat Detectors (LHD).

### 15.27 EMC Testing

15.27.1 The Contractor shall perform measurements to demonstrate EMC requirements specified in Clause 2.15 ERTS have been achieved. Demonstration of EMC compliance shall be considered a type test requirement.

### 15.28 Integrated Testing with Signalling and Train Control, and Telecommunications Contractors

15.28.1 Integrated testing of each car shall comply with the accepted international standards agreed between the Contractors as agreed with the Engineer. Integration testing shall be done at the rolling stock factory and main line to ensure satisfactory performance of all train control and telecommunications interfaces. The test certificate subsequently shall be issued jointly by the Rolling Stock, Signalling and Train Control and Telecommunications contractors.

15.28.2 In case of ATO, the Integration test between the Rolling Stock, and Signalling and Train Control contractors shall include tests on mainline to confirm the realisation of demanded acceleration and deceleration rate by the ATO under various conditions.

15.28.3 See Appendix TD for details.

### 15.29 Type Test Witness

No.	System /Subsystem Type tests
1.	Combined system tests
2.	Compression load test of carbody
3	Bogie incl. X factor
4	HVAC system test incl. FAI
5	Traction motor & gear case
6	Converter /inverter
7	Auxiliary converter
8	Brake system
9	Transformer
10	Doors incl. FAI
11	TCMS
12	Power Electronics



13	PIS & CCTV
14	Prototype train Inspection Hold Points (2) Final Prototype Inspection

**15.30 Deliverables**

15.30.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	15.5.5	Software package required for analysis of the raw data acquired during oscillation trials.	One set at nominated depot.

**Note:**

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.

**APPENDIX TA. INTERNATIONAL STANDARDS****TA1 General**

TA1.1 Standards are set out in alphabetical order of the Standards Organization (in English) in tables TA1.1 to TA1.19. Many of the standards included in the listing are suggested as guidance only.

Table TA1.1: American Society for Testing and Materials Standards

Standard Organization	Standard Reference Number	Title or Description of the Standard
ASTM	A 480	Standard specification for general requirements for flat rolled stainless and heat resisting steel plates.
ASTM	B 280	Standard Specification for Seamless Copper Tube for Air Conditioning and Refrigeration Field Service.
ASTM	B743	Standard Specification for Seamless Copper Tube in Coils.
ASTM	D 2563	Standard Practice for Classifying Visual Defects in Glass-Reinforced Plastic Laminate Parts1.

Table TA1.2: British Standards Institution

Standard Organization	Standard Reference Number	Title or Description of the Standard
BS	88	Cartridge Fuses for Voltages up to and including 1000V AC and 1500V DC.
BS	476-7	Flame Spread Requirements for Paint
BS	476-15 : 1993 ISO 5660-1 : 1993	Fire Test on Building Materials and Structures : Method of Measuring the Rate of Heat Release of Products.
BS	857:1990	Specification for Safety Glass for Land Transport.
BS	1571 : Pt. 2 1984	Methods for Simplified Acceptance Testing of Air Compressors and Exhausters : Part 2 : Simplified testing of reciprocating and rotating types, including permissible deviations pressure and temperature measurements and arrangement of tests, form of test report and gives adjustment of test result to guarantee conditions.
BS	1725 Pt. 1	Domestic furniture - Beds and mattresses - Safety requirements and test methods.
BS	3100:1991	Specification for Steel Castings for General Engineering Purposes. Chemical Composition Heat treatment and Mechanical Properties of Cast Steels.
BS	3682 Pt.1: 1994	Specification for Compressed Air Brake Hose.
BS	3900:1980	Methods of Test for Paint.
BS	4066	Cable Tests in Fire Conditions.
BS	4360 :	Steel Used in Welded Structures.
BS	4579: Pt.1 1988	Compression Joints in Copper Conductors. Covers requirements for the performance of general application compression joints for use with copper and copper alloy conductors up to 1000mm <sup>2</sup> cross sectional area operating below 85°C.
BS	4743	Specification for Safety Requirements for Electronic Measurement Apparatus.



BS	4870	Specification for Approval Testing of Welding Procedures.
BS	4870 : Pt.3 1985	Arc Welding of Tube to Tube-Plate Joints in Metallic Materials. Welding procedure tests, approval & its extent, test joints, examination and testing, results.
BS	4870 : Pt.4 1988	Specification for Automatic Fusion Welding of Metallic Materials including Welding Operator Approval. Approval testing of procedures, programmes, systems, and operators for automatic or robotic welding. Items in welding procedure test, changes affecting approval, extent of approval, examination and testing.
BS	5135:1984	Specification of Arc Welding of Carbon and Carbon Manganese Steels. Parent metals , welding consumables, butt and fillet weld details, preparation and assembly, procedures to avoid cracking, welding procedure details, approval of welders, inspection and testing. Appendices on design, typical weld details, avoidance of hydrogen cracking, solidification cracking, lamellar tearing and guidance on acceptance levels.
BS	6656	Prevention of inadvertent ignition of flammable atmospheres by radio frequency radiation
BS	7371 Pt. 10 : 1994	Specification for Organic Coatings (The Deltaseal Process)

Table TA1.3: British Standards Institution/Euro Normes

Standard Organisation	Standard Reference Number	Title or Description of the Standard
BS-EN	3	Portable Fire Extinguishers.
BS-EN	286-3:1995	Simple Pressure Vessels designed for Air Braking and Auxiliary Pneumatic Equip-ment for Railway Rolling Stock.
BS-EN	286-4:1995	Simple Unfired Pressure Vessels Designed to Contain Air or Nitrogen. Aluminium Alloy Pressure Vessels for Air Braking Equipment and Auxiliary Equipment for Rolling Stock.
BS-EN	287-1 : 1992	Specification of Approval Testing of Welders Working to Approved Welding Procedures : Pt. 1 Fusion Welding of Steel.
BS-EN	288-3 : 1993	Fusion Welding of Steel
BS-EN	10025	Hot Rolled Products of Non-Alloy Struct-ural Steels. Technical delivery conditions. Requirements for long and flat products.
BS-EN	10210	Hot Finished Structural Hollow Sections of Non-Alloy and Finer Grain Structural Steels.
BS-EN	24014 : 1992	Hexagon Head Bolts. Product grades A, B.
BS-EN	24017 : 1992	Hexagon Head Machine Screws. Product grades A and B.
BS-EN	30042 : 1994	Arc Welded Joints in Aluminium and its Weldable Alloys. Guidance on quality levels for imperfections.
BS-EN	50081	Electromagnetic Compatibility. Generic emission standard.
BS-EN	60529 :1992	Specification for Degrees of Protection Provided by Enclosures (IP Code). Gives

		uniformity in methods of describing protection provided by enclosures and in tests to prove protection. Provides an optional extension of the IP code by an additional letter A – D, if the actual protection of persons against access to hazardous parts is higher than that indicated by the first characteristic numeral.
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Table TA1.4: CISPR

Standard Organisation	Standard Reference Number	Title or Description of the Standard
CISPR	16 am1 (1997-08)	Specification for Radio Disturbance and Immunity Measuring Apparatus and Methods : 1 Radio Disturbance and Immunity Measuring Apparatus

Table TA1.5: Defence Standards

Standard Organisation	Standard Reference Number	Title or Description of the Standard
DEF-STD-	00-56	Hazard Analysis

Table TA1.6: German Standards / Deutsches Institut fur Normung

Standard Organisation	Standard Reference Number	Title or Description of the Standard
DIN	2353 : 1998	Compression fittings and couplings

Table TA1.7: Euro Normes

Standard Organisation	Standard Reference Number	Title or Description of the Standard
EN	438-2	High-pressure decorative laminates (HPL) - Sheets based on thermosetting resins (Usually called Laminates) - Part 2: Determination of properties
EN	779	Particulate air filters for general ventilation - Determination of the filtration performance
ECE	Regulations-43	Uniform provisions concerning the Approval of safety glazing and glazing materials
EN	10089	Hot rolled steels for quenched and tempered springs - Technical delivery conditions
EN	10155	Structural Steels with improved atmospheric Corrosion
EN	12663	Railway applications Structural requirements of railway vehicle bodies
EN	13103	Railway applications – Wheelsets and bogies Non-powered axles – Design method
EN	13104	Railway applications – Wheelsets and bogies Powered axles – Design method
EN	13261	Railway applications –Wheelsets and bogies Axles – Product requirements
EN	13262	Railway applications - Wheelsets and bogies - Wheels - Product requirements
EN	13272	Electrical Lighting in Rolling Stock
EN	13452	Railway applications - Braking - Mass transit brake systems
EN	13452-1	Railway applications - Braking - Mass transit brake systems : Performance Requirements.



EN	13749	Railway applications - Wheelsets and bogies method of specifying the structural requirements of bogie frames
EN	14363	Railway applications. Testing and Simulation for the acceptance of running characteristics of railway vehicles. Running Behaviour and stationary tests
EN	14750-1	Railway applications - Air conditioning for urban and suburban rolling stock Part 1: Comfort parameters
EN	14750-2	Railway applications - Air conditioning for urban and suburban rolling stock Part 2: Type tests
EN	14750:2005	Railway applications - Bodyside entrance systems
EN	14752:2015	Railway applications - Bodyside entrance systems for Rolling Stock.
EN	15152	Railway applications- Front windscreens for train cabs.
EN	15227	Railway applications - Crashworthiness requirements for railway vehicle bodies.
EN	45545 Part 1 to 7 (Category 4-A, Hazard level HL3) latest edition	Railway applications – Fire protection on railway vehicles – Part 1-7.
EN	50082	EMC
ENV	50121	Railway Application – Electro-Magnetic Compatibility – Rolling Stock
EN	50121-1 : 1996	Railway Application – Electro-Magnetic Compatibility Part 1. General
ENV (DD)	50121-2 : 1996	Railway Application – Electro-Magnetic Compatibility Part 2. Emission of the Whole Railway System to the Outside World.
EN	50121-3	Railway Application – Electro-Magnetic Compatibility – Rolling Stock
EN	50122-1	Railway Applications - fixed installations - part 1_protective provisions relation to electrical safety and earthing
EN	50264	Railway Application- Railway Rolling Stock cables having special fire performance
EN	50126	Railway Application – Specification and Demonstration of RAMS
EN V	50121-3-1	Railway Application – Electro-Magnetic Compatibility – Rolling Stock Pt. 3–1 : Train and Complete Vehicle. traction stock, train sets and independent hauled stock. Covers the frequency range DC to 400GHz.
EN	50121-3-2	Railway Application – Electro-Magnetic Compatibility – Pt. 3–2 : Rolling Stock Apparatus. Specifies emission and immunity requirements for electrical and electronic apparatus for use on rolling stock. Covers the frequency range DC to 400GHz.
EN	50124-1	Electrical Enclosures
EN	50124-2	Railway applications- Insulation Coordination- Part 2: Overvoltages and related protection
EN	50126-2	Railway Applications – Dependability for Guided Transport System - Pt. 2 : Safety
EN	50128	Railway Applications : Software for Railway Control and Protection Systems

EN	50129	Safety Related Electronic Railway Control and Protection Systems
EN	50132-7	Alarm systems - CCTV surveillance systems for use in security applications - Part 7: Application guidelines.
EN	50155	Railway Application - Electronic equipment used on Rolling stock.
EN	50163	Lightning Arrestors.
EN	50200-PH-15	Fire Resistant Cables
EN	50200-PH-90	Fire resistant LSZH cables
EN	50207	Power Converters for Rolling Stock
EN	50264 1 to 3	Railway Applications - Railway Rolling Stock Power and Control Cables having special fire performance.
EN	50306 Part 1 to 4	Railway Rolling Stock cables having special fire performance.
EN	50388	Railway Applications. Power supply and rolling stock. Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability.
EN	50405	Railway applications - Current collection systems - Pantographs, testing methods for carbon contact strips.
EN	50533	Railway applications - Three-phase train line voltage characteristics.
EN	50547	Railway applications. Batteries for auxiliary power supply systems.
EN	55011	Industrial, scientific and medical equipment radio-frequency equipment – disturbance characteristics – limits and methods of measurement.
EN	55101	Immunity of information Technology Equipment.
EN ISO	2813	Determination of specular gloss of non-metallic paint films.

Table TA1.8: International Electro-technical Commission

IEC	815	Guide for the selection of insulators in respect of polluted conditions.
IEC	1133	Electric traction-Rolling stock-Test methods for electric and thermal/electric rolling stock on completion of construction and before entry into service.
IEC	300-3-3	Dependability management – Part 3: Application guide Section 3: Life Cycle coasting.
IEC	60034-1 : (1996-12) 60034-1 : am1 (1997-06)	Rotating Auxiliary Machines : Pt. 1 Rating and Performance Amendment No.1
IEC	60034-7	Rotating Auxiliary Machines : Pt. 7 Rating and Performance.
IEC	60044	Instrument transformers.
IEC	60044-1	Instrument transformers - Part 1 Current transformers.
IEC	60044-2	Instrument transformers- Part 2- Inductive voltage transformers.
IEC	60056 (1987-03) 60056 am3 (1996-10)	High Voltage Alternating Current Circuit Breakers Amendment No.3



IEC	60068-2	Environmental Testing.
IEC	60076	Power Transformers.
IEC	60077 (1968-01)	Specification for Electric Traction Equipment. Motive power units of 600-3000V DC or high-voltage AC or independent power source, also for control trailers or multiple unit trains. Can be applied to DC rolling stock at voltages below 600V.
IEC	60077-1	Railway applications-Electric equipment for rolling stock- Part1 – General service conditions and general rules.
IEC	60077-2	Railway applications-Electric equipment for rolling stock-Part 2 - Electrotechnical components-General rules.
IEC	60077-4	Railway applications- Electric equipment for Rolling Stock Part 4: Electrotechnical components Rules for AC circuit breakers
IEC	60099-4 (1991-11)	Surge Arrestors – Pt.4 Metal Oxide, without Gaps for AC Systems.
IEC	60115-1	Smaller Resistors.
IEC	60228	Cables.
IEC	60268-1 (1985-01) 60268-1 60268-1 (1988-01)	Sound System Equipment : Pt. 1 General. Amendment 1 Amendment 1
IEC	60268-16 Part 16	The Objective Rating of Speech Intelligibility in Auditoria by the "RASTI" Method
IEC	60269-1 1998-12	Low Voltage Fuses Pt. 1 : General Requirements.
IEC	60269-2 am1 (1995-11)	Low Voltage Fuses Pt. 2 : Supplementary Requirements for Fuses for Use by Authorised Persons (Fuses mainly for Industrial Applications).
IEC	60300-1 (1993-04)	Dependability Management – Pt. 1 Dependability Programme Management.
IEC	60300-2 (1995-12)	Dependability Management – Pt. 2 Dependability Programme Elements and Tasks.
IEC	60300-3-1 (1991-11)	Dependability Management – Pt. 3 Application Guide Sct. 1 Analysis Techniques for Dependability. Guide on Methodology
IEC	60300-3-2 (1993-10)	Dependability Management – Pt. 3 Application Guide Sct. 2 Collection of Dependability Data from the Field.
IEC	60300-3-3 (1996-09)	Dependability Management – Pt. 3 Application Guide Sct. 3 Life Cycle Costing.
IEC	60300-3-5	Dependability management – Part 3-5: Application guide – Reliability test conditions and statistical test principles.
IEC	60310 1991-11)	Traction Transformers and Inductors.
IEC	60319 1978-01	Presentation of Reliability Data on Electronic Components (or Parts).
IEC	60322	Railway applications -Electric equipment for rolling stock - Rules for power resistors of open construction.
IEC	60326-3 : 1991 BS 6221 : Pt.3 : 1991	Guide for the design and use of printed wiring boards. Design and application of printed boards, irrespective of their method of manufacture.

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		Recommends design, specification, and application.
IEC	60332-1 1993-04	Tests on Electric Cables under Fire Conditions – Pt.1 :Test on a Single Vertical Insulated Wire or Cable
IEC	60332-3 1992-03	Tests on Electric Cables under Fire Conditions – Pt.3 : Tests on Bunched Wires or Cables.
IEC	60349 1991-12	Electric Traction. Rotating Electrical Machines for Rail and Road Vehicles.
IEC	60349-1	Electric Traction – Rotating Electrical Machines for Rail and Road Cars.
IEC	60349-2 1993-04	Electric Traction – Rotating Electrical Machines for Rail and Road Vehicles Pt. 2 Electronic Converter-fed AC Motors.
IEC/TR2	60349-3 1995-08	Electric Traction – Rotating Electrical Machines for Rail and Road Vehicles Pt. 3 Determination of the Total Losses of Converter-fed Alternating Current Motors by Summation of the Component Losses.
IEC	60384-1	Electrolytic Capacitors.
IEC	60384-4	Electrolytic Capacitors.
IEC/TR	60411-2 (1978-01)	Power Convertors for Electric Traction Pt. 2 Additional Technical Information.
IEC	60494 1974-01	Rules for Pantographs of Electric Rolling Stock.
IEC	60494-2	Railway applications - Rolling stock - Pantographs Characteristic and tests -Part 2: Pantographs for metros and light rail vehicles.
IEC	60502	High Voltage Cables.
IEC/TR	60505 1975-01	Guide for the Evaluation and Identification of Insulation Systems of Electrical Equipment.
IEC	60529	IP Codes, etc.
IEC	60563	Permissible Limiting Temperatures in Service for Components of Electrical Equipment of Traction Vehicles.
IEC	60571 Latest version	Electronic Equipment Used on Rail Vehicles.
IEC	60571-1	Electronic Equipment Used on Rail Vehicles.
IEC	60571-2	Electronic Equipment Used on Rail Vehicles.
IEC	60571-3	Electronic Equipment Used on Rail Vehicles.
IEC	60605	Reliability and maintainability Requirements in Equipment.
IEC	60617	Graphical Symbols For Diagrams.
IEC	60617-1 (1985-01)	Graphical Symbols For Diagrams : Pt. 1 General Information, General Index. Cross Reference Tables.
IEC	60617-2 (1996-05)	Graphical Symbols For Diagrams : Pt. 2 Symbol Elements, Qualifying Symbols and Other Symbols Having General Application.
IEC	60617-3 (1996-05)	Graphical Symbols For Diagrams : Pt. 3 Conductors and Connecting Devices.
IEC	60617-4 (1996-06)	Graphical Symbols For Diagrams : Pt. 4 Passive Components.
IEC	60617-5 (1996-06)	Graphical Symbols For Diagrams : Pt. 5 Semiconductors and Electron Tubes.
IEC	60617-6 (1996-05)	Graphical Symbols For Diagrams : Pt. 6 Production & Conversion of Electrical Energy.
IEC	60617-7 (1996-05)	Graphical Symbols For Diagrams : Pt. 7 Switch gear, Control gear, and Protective Devices.



IEC	60617-8 (1996-05)	Graphical Symbols For Diagrams : Pt. 8 Measuring Instruments, Lamps and Signalling Devices.
IEC	60617-9 (1996-05)	Graphical Symbols For Diagrams : Pt. 9 Telecommunications Switching & Peripheral Equipment.
IEC	60617-10 (1996-05)	Graphical Symbols For Diagrams : Pt. 10 Telecommunications Transmission.
IEC	60617-11	Graphical symbols for diagrams - Part 11: Architectural and topographical installation plans and diagrams.
IEC	60617-12	Graphical symbols for diagrams - Part 12: Binary logic elements.
IEC	60617-13	Graphical symbols for diagrams - Part 13: Analogue elements.
IEC	60623 1990-03 60623 am1 1992-04	Vented Nickel Cadmium Prismatic Rechargeable Single Cells. Amendment No. 1
	60623 am2 1992-07	Amendment No. 2
IEC	60631	Electro-dynamic Braking.
IEC	60664	Surface Creepage and Electrical Clearance.
IEC	60721	Classification of environmental Conditions - Part 1 : Environmental parameters and their severities.
IEC	60747-6	Electrical Type Test.
IEC	60749	Mechanical and Climatic Test Methods.
IEC	60754-1 1994-01	Tests on Gases Evolved During Combustion of Materials from Cables Pt. 1 : Determination of Amount of Halogen Acid Gas.
IEC	60754-2 1991-08	Tests on Gases Evolved During Combustion of Materials from Cables Pt. 2 : Determination of Amount of Halogen Acid Gas.
	60754-2 1997-04	Amendment No. 1
IEC	60850 (1988-03)	Supply Voltages for Traction Systems.
IEC	60871-1 (1997-10)	Shunt Capacitor for AC Power Systems having a Rated Voltage above 1000V – Pt. 1 General Performance, Testing and Rating – Safety Requirements – Guide for Installation and Operation.
IEC	60913 (1988-12)	Electric Traction Overhead Lines.
IEC	60947-1 (1998-11)	Low Voltage Switch Gear and Control Gear Pt.1 General Rules.
IEC	60947-2 (1998-03)	Low Voltage Switch Gear and Control Gear Pt.2 Circuit Breakers.
IEC	60947-3	Circuit Breakers
IEC	60947-4	Circuit Breakers
IEC	60993 (1989-08)	Electrolyte for Vented Nickel-Cadmium Cells.
IEC/TR3	61000-1-1 (1992-05)	Electro-magnetic Compatibility EMC) Pt. 1 : General
IEC	61000-3-6	Electromagnetic Compatibility (EMC) - Part 3-6: Limits - Assessment of emission limits for the connection of distorting installations to MV, HV and EHV power systems.
IEC	61000-4-2 (1995-01)	Testing and Measurement Techniques Pt. 4, Sct. 2 : Electrostatic Discharge Immunity Test.



	61000-4-2 am1(1998-01)	Amendment No. 1
IEC	61000-4-3 (1995-03)	Testing and Measurement Techniques Pt.4 Sct 3 : Radiated Radio Frequency Electromagnetic Field Immunity Tests.
	61000-4-3 am1(98-06)	Amendment No. 1
IEC	61000-4-4 (1995-01)	Testing and Measurement Techniques Pt.4 Sct. 4 : Electrical Fast Transient/Burst Immunity Test.
IEC	61000-4-5 (1995-03)	Testing and Measurement Techniques Pt.4 Sct. 5 : Surge Immunity Test.
IEC	61000-4-6 (1996-04)	Testing and Measurement Techniques Pt.4 Sct. 6 : Immunity to Conducted Disturbances Induced by Radio Frequency Fields.
IEC	61000-4-8 (1993-06)	Testing and Measurement Techniques Pt.4 Sct.8 : Power Frequency Magnetic Field Immunity Test.
IEC	61000-4-9 (1993-06)	Testing and Measurement Techniques Pt.4 Sct. 9 : Pulse Magnetic Field Immunity Test.
IEC	61000-4-10 (1993-06)	Testing and Measurement Techniques Pt.4 Sct. 10 : Damping Oscillatory Magnetic Field Immunity Test.
IEC	61000-4-11 (1993-06)	Testing and Measurement Techniques Pt.4 Sct. 11: Voltage Dips, Short Interruptions and Voltage Variations Immunity Test.
IEC	61000-4-12 (1993-06)	Testing and Measurement Techniques Pt.4 Sct. 12 : Oscillatory Waves Immunity Test.
IEC	61000-5-1 (1996-12)	EMC Pt. 5 :Installation and Mitigation Guidelines Sct. 1 General Considerations.
IEC	61000-5-2 (1996-12)	EMC Pt. 5 :Installation and Mitigation Guidelines Sct. 2 Earthing and Cabling.
IEC	61034	Cables.
IEC	61071-1	Power Electronic Capacitors.
IEC	61131	Programmable controllers.
IEC	61133 (1992-11)	Electric Traction – Rolling Stock – Test Methods for Electric and Thermal/ Electric Rolling Stock on Completion of Construction and Before Entry into Service.
IEC	61287-1 (1995-07)	Power Converters Installed on Board Rolling Stock – Part 1 Characteristics and Test Methods.
IEC	61287-2 Latest version	Power convertors installed on board railway rolling stock – Part 2: Additional technical information.
IEC	61371	Shocks and vibrations standards.
IEC	61373	Requirements for Vibration and Shock Testing of Equipment for Railway Cars.
IEC	61375-1	Electronic railway equipment - Train Communication Network - Part 1: TCN Communication Network General Architecture.
IEC	61375-2-5	Electronic railway equipment - Train Communication Network - Part 2 - 5: ETB - Ethernet Train Backbone.
IEC	61375-3-4:2014	Electrical equipment and systems for railways.
IEC	61377 (1996-05)	Electric Traction – Rolling Stock –Combined Testing of Inverter Fed Alternating Current Motors and their Control.
IEC	61508-1 1998-12	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-Related Systems : Part 1. General Requirements.
IEC	61508-3 1998-12	Functional Safety of Electrical/Electronic/Programmable Electronic



		Safety-Related Systems : Part 3. Software Requirements.
IEC	61881	Power Electronic Capacitors used on Rolling Stock.
IEC	62313	Railway applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock.
IEC	62290-1 (2006)	Railway applications –Urban guided transport management and command/control systems – Part 1: System principles and fundamental concepts.

Table TA1.9: Institution of Electrical and Electronics Engineers

Standard Organisation	Standard Reference Number	Title or Description of the Standard
IEEE	16	Standard for Electrical and Electronic Control Apparatus on Rail Vehicles.
IEEE	1474.1	Communications-Based Train Control (CBTC) Performance and Functional Requirements.
IEEE	304	Thermal Endurance of Insulation.
IEEE	429	Sealing Against Moisture.
IEEE	519 – 1992, 2014	IEEE Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems.

Table TA1.10: Indian Railways Standards

Standard Organisation	Standard Reference Number	Title or Description of the Standard
IRS	R16	Unpowered Axles for Broad Gauge Vehicles.
IRS	R19	Wheels for Broad Gauge Vehicles.
IRS	R43	Powered Axles for Broad Gauge Vehicles.

Table TA1.11: Indian Standard

Standard Organisation	Standard Reference Number	Title or Description of the Standard
IS	2553 (Part 1 & 2)	Safety Glass - Specification Part 1: General Purpose Part 2 : For Road Transport
IS	8148	Packaged air conditioners - specification.

Table TA1.12: International Standards Organisation

Standard Organisation	Standard Reference Number	Title or Description of the Standard
ISO	281/1	Steel for Railway Wheels.
ISO	1553	Methods of the Determination of Copper, Lead, Iron, Aluminium and Nickel in Copper Alloys.
ISO	1554	
ISO	1810	
ISO	1217:1996	Displacement compressors - Acceptance Tests.
ISO	2439	Flexible cellular polymeric materials – Determination of hardness(indentation technique).
ISO	2553	Welding & allied processes- Symbolic representation on drawings- Welded joints



ISO	2631 -1(1997)	Mechanical Vibration and Shock – Evaluation of Human Exposure to Whole Body Vibration
ISO	2631-4(2001)	Mechanical vibration and shock- Evaluation of human exposure to whole- body vibration- Part 4: Guidelines for the evaluation of the effects of vibration and rotational motion on passenger and crew comfort in fixed- guideway transport systems.
ISO	3095	Acoustics – Measurement of Noise Emitted by Railbound Vehicles 1 <sup>st</sup> . Edition.
ISO	3381	Acoustics – Measurement of Noise Inside Railbound Vehicles 1 <sup>st</sup> Edition.
ISO	4649	Rubber, vulcanized or thermoplastic- Determination of Abrasion resistance using a rotating cylindrical drum device
ISO	7626-5	Vibration and shock - Experimental determination of mechanical mobility.
ISO	8573	Compressed air quality standard.

Table TA1.13: International Standards Organisation

Standard Organisation	Standard Reference Number	Title or Description of the Standard
ISO	9000	Design Management and Control. Quality Systems : Model for Quality Assurance in Design, Development, Production, Installation and Servicing .
ISO	9001	
ISO	9002	
ISO	9614-2	Acoustics - determination of sound power levels of noise sources using sound intensity - part 3_ precision method for measurement by scanning.
ISO	9662	Information Processing – Volume and File Structure of CD-ROM for Information Exchange.

Table TA1.14: Japan Industrial Standards

Standard Organisation	Standard Reference Number	Title or Description of the Standard
JIS	G 3114	Hot rolled atmospheric corrosion resisting steels for welded structure.
JIS	G 3459	Stainless steel pipes.
JIS	G 4305	Cold rolled stainless steel plates, sheets and strip 50126.

Table TA1.15: Military Standards

Standard Organisation	Standard Reference Number	Title or Description of the Standard
MIL-HDBK-	454 (1)	General Guidelines for Electronic Equipment.
MIL-I-	46058	Insulating Compound (for Coating Printed Circuit Assemblies).
MIL-STD-	882 C	Hazard Analysis.
MIL-STD-	883 E (1)	Test Methods Standard Microcircuits.
MIL-STD-	889 B (3)	Dissimilar Metals.

Table TA1.16: French Standards (Normes Françaises)

Standard Organisation	Standard Reference Number	Title or Description of the Standard
NF-F	31-112	Railway Rolling Stock – Protection in Relation to Graffiti – Tests Procedures and Methods of Valuation, Behaviour of Materials and Products of Expulsion



NF-F	31-119	Behavior of seats at static, fatigue, vibrations and impact stresses
NF-F	01-281	Fibre reinforced thermosetting plastics
NF-F	63-808	Halogen Free Cables for Low Voltage Applications
NF-F	63-826	Halogen Free Cables for High Voltage Applications
NF	T51-113	Plastic Materials Determination of Resistance to Scratching

Table TA1.17: Research and Study Organisation (ORE)

Standard Organisation	Standard Reference Number	Title or Description of the Standard
ORE	C116/RP8	DB WZ Ride Index : Frequency Weighting Curves

Table TA1.18: International Railway Union

Standard Organisation	Standard Reference Number	Title or Description of the Standard
UIC	410 O	Composition and Calculation of the Weight and Braking of Passenger Trains
UIC	510-2 OR	Trailing stock: wheels and wheelsets. Conditions concerning the use of wheels of various diameters
UIC	515 OR	Passenger rolling stock trailer bogies - running gear
UIC	515-3 OR	Rolling Stock – Bogies – Running gear – Axle design calculation method
UIC	515-4 O	Passenger Rolling Stock – Trailer bogies – Running gear – Axle design calculation method
UIC	518 OR	Testing and Approval of railway Vehicles from the Point of View of their Dynamic Behaviour, Safety, Track fatigue and Ride Quality.
UIC	534 OR	Signal lamps and signal lamp brackets for locomotives, railcars and all tractive and self propelled stock.
UIC	541	Brakes – All UIC 541 Standards
UIC	541-5 OR	Brakes – Electropneumatic brakes for passenger trains and freight trains.
UIC	541-6 OR	Brakes – Electropneumatic brakes test programmes for passenger trains and freight trains.
UIC	555 OR	Electric lighting in passenger rolling stock.
UIC	555-1 OR	Transistorised inverters for supplying fluorescent lamps (1).
UIC	560 OR	Doors of coaches and luggage vans.
UIC	564-2 OR	Regulations Relating to Fire Protection and Fire Fighting Measures in Passenger Carrying Railway Vehicles.
UIC	566 OR	Loadings of coach bodies and their components.
UIC	615 OR	Tractive units-Bogies and running gear.
UIC	615-1 OR	Tractive units – Bogies and running gear – General conditions applicable to component parts.
UIC	615-4 OR	Motive power units - Bogies and running gear – Bogie frame structure strength test

UIC	651	Layout of driver's cabs in locomotives, railcars, multiple unit trains and driving trailers.
UIC	811-1 OR	Technical Specification for the Supply of Axles for Tractive and Trailing Stock
UIC	812-2 OR	Solid Wheels for Tractive and Trailing Stock Tolerances (1).
UIC	812-3	Technical Specification for the Supply of Solid Wheels for Trailing Stock.
UIC	813 O	Technical Specification for the Supply of Wheelsets for Tractive and Trailing Stock : Tolerances and Assembly.
UIC	861-3	Standard 60 kg/m rail profiles.
UIC	S1002	Standardization of wheel profile.

Table TA1.19: Miscellaneous

Standard Organisation	Standard Reference Number	Title or Description of the Standard
ASHRAE	37	Methods of Testing for Rating Electrically Driven Unitary Air-Conditioning and Heat Pump Equipment.
ASHRAE	55	Thermal environmental conditions for human occupancy.
ASHRAE	62	Ventilation for Acceptable Indoor Air Quality.
ASHRAE Handbook Fundamentals		
ARGE Guidelines		Fire detection in rolling stock.
ANSI/AMCA	204	Balance Quality and Vibration Levels for Fans.
ANSI	B 31.5	Refrigeration Piping and Heat Transfer Components.
Railway Group Standard	GM/RT 2130	Vehicle Fire, Safety and Evacuation.
Railway Group Standard	GM/RT 2472:2002	Requirements for Data Recorders on Trains.

1. All sub-systems including major equipment, assemblies and complete car/train must comply with the latest international standards.
2. The above list is for guidance only. Wherever update standard is released, the same shall be applicable.
3. The Contractor shall provide the relevant Standard in soft copy to DMRC for reference.



## APPENDIX TB. CAR BODY MOCK-UPS

	Type of Mock-up		Type of Part used			Remarks
	1:1 Physical Mock up	Digital Mock up (if any)	Dummy	Imitation	Real (If applicable)	
<b>TB 1 Car-body Mock-up</b>						
<b>TB1.1 The mock-up shall show at least two full seating bays, with typical passenger doorway between, gangway and interfaces, including the interior details and finishes. The mock-up shall demonstrate, as a minimum, the following:</b>						
(i) Location and type of seating (as actual).	✓				✓	
(ii) Location of grab poles & bars, grab handles.	✓				✓	
(a) Location of grab poles	✓				✓	
(b) Location of bars	✓				✓	
(c) Location of grab handles.	✓				✓	
(d) Any other item as required by the Engineer	✓				✓	
(iii) Accessibility for wheelchairs between grab-poles, to seating areas, and between cars.	✓				✓	
(iv) Wheelchair position.	✓				✓	
(v) Interior finishes and colours.	✓				✓	
(a) Electric locker panels	✓				✓	
(b) End ceiling panel	✓				✓	
(c) Inspection cover panels	✓				✓	
(d) Body side lower panel	✓				✓	
(e) Window mask panels	✓				✓	
(f) Ceiling panels	✓				✓	
(g) In fill strip panels	✓				✓	
(h) Door coving panels, Ceiling coving panels	✓				✓	
(i) Floor (Floor construction, Floor covering)	✓				✓	
(j) Mark Label	✓				✓	

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(k) Advertisement card rack	✓					✓
(l) Draught screen	✓					✓
(m) Air diffuser & duct	✓					✓
(n) Return air grille	✓					✓
(o) Speaker	✓					✓
(p) Threshold plate	✓					✓
(q) Car end fairing	✓				✓	-
(r) ECU Terminal	✓				✓	
(s) Panto control panel	✓					
(t) Any other item as required by the Engineer	✓					
(vi) Location and performance of the Passenger Information Display System (PIDS), LCD based route maps, Passenger Saloon Surveillance System (PSSS). At least one PID, one route map and one PSSS camera shall be operable in the final version of this mock-up. LCDs for advertisements (as actual)	✓				✓	
(a) Passenger Information Display System(PIDS)	✓					✓
(b) LCD based route Maps	✓					✓
(c) Passenger Saloon Surveillance System(PSSS)	✓					✓
(d) Any other item as required by the Engineer	✓					✓
(vii) Lighting levels.	✓					✓
(viii) Location of fire extinguishers	✓					✓
(ix) Quantity and locations of system route maps, advertising cards and other signage.	✓					✓
(x) Location of and access to Passenger Alarm device allowing two-way speech channel to be established with train operator.	✓				✓	
(xi) Flooring, embedded stickers on floors including fluorescent types	✓					✓
(xii) Stickers & labels	✓					✓
(xiii) Mounting of display panels	✓					✓
(xiv) FRP modules	✓					✓
(xv) Flooring	✓					✓
(xvi) Window	✓					✓
(xvii) FRP	✓				✓	✓
(xviii) Display (PID)	✓					✓
(xix) Location of equipment, access, ventilation, etc.	✓				✓	✓
(xx) Seats-Access to equipment	✓					✓
(xxi) Air circulation arrangement compliance with CFD simulation design (Air duct)	✓					✓

(xxii) CCTV coverage and blind spots	✓					✓
(xxiii) Interior lighting	✓					✓
(xxiv) Fire detector	✓					✓
<b>TB 2 Car-body Engineering Mock-up</b>						
<b>TB2.1 A Car-body Engineering Mock-up shall be provided for review by the Engineer at the Contractor's manufacturing facility. It shall demonstrate, as a minimum, the following:</b>						
(i) Location and access to light fittings.	✓					✓
(ii) Location of and access to air-conditioning diffusers and ducting.	✓				✓	
(iii) Location of and maintenance access to door drive mechanisms.	✓					✓
(iv) Access for window replacement.	✓					✓
(v) Access to equipment cupboards	✓					✓
(vi) Access to Passenger Information Display system.	✓				✓	
(vii) Gangway to car-end interface.	✓				✓	
(viii) Access to Electrical control (relay and MCB etc.) panels	✓				✓	
<b>TB 3 Cab Mock-up</b>						
<b>TB3.1 All controls and indications shall be those proposed for the final build. The actual train operator's seat shall be installed. The mock-up shall include as a minimum the following:</b>						
(i) Operation and adjustment of Train operator's seat.	✓					✓
(ii) Location of and access to all train operator's controls and instrumentation.	✓					✓
(a) Driver's Console	✓					✓
(b) Master Controller	✓				✓	
(c) VDU	✓				✓	
(d) Speed Meter	✓				✓	
(e) Brake Valve	✓			✓		
(f) Double Pressure Gauge	✓			✓		
(g) Radio Hand Set	✓					✓
(h) Operating Panel	✓				✓	
(i) Wiper control switch	✓			✓		
(j) Any other item as required by the Engineer	✓					✓
(iii) Location of and access to light fittings.	✓					✓
(iv) Location and stowage of, and access to safety equipment.	✓					✓
(a) Fire Extinguisher	✓					✓
(b) First Aid Box	✓			✓		





(xiii) Location of Forward Facing and Rear Viewing PSSS camera.	✓				✓
(xiv) Master control panel layout & type.	✓				✓
(xv) Layout of VDU (Video Display Unit)	✓				✓
(xvi) Layout of Operating panel	✓				✓
(xvii) Encapsulation arrangement	✓				✓
(xviii) Cab-saloon partition before & after removal	✓				✓
(xix) Utilisation of additional space released after GOA3/4, lumber-support, front visibility, etc.	✓				✓
(xx) Equipment location details	✓		✓		✓
<b>TB 4 Cab Front End Mock-up</b>					
<b>TB4.1 The front-end mock-up shall demonstrate, as a minimum, the following:</b>					
(i) Colour and form of the cab car external front end.	✓				✓
(ii) Indication of the crashworthiness structural features.	✓				✓
(iii) Location of and access to windscreen wipers, lights, horns, and other equipment mounted on the front of the cab car.	✓		✓		✓
(a) Wiper	✓				✓
(b) Wiper Motor Assembly	✓				✓
(c) Head light, Tail Light, Flasher Light	✓				✓
(d) Horn	✓				✓
(e) Cab Mask, Cab skirts	✓				✓
(f) Hand rail	✓				✓
(g) Cable	✓				✓
(h) Any other item as required by the Engineer	✓				✓
(iv) Location of auto-coupler and associated accoutrements.	✓		✓		✓
<b>TB 5 Emergency De-trainment Device Mock-up</b>					
<b>TB5.1 The emergency de-trainment device mock-up shall be able to demonstrate, as a minimum, the following:</b>					
(i) Front visibility and aesthetics	✓				✓
(ii) Security when stowed.	✓				✓
(iii) Method and force required for deployment of folding ramp and handrails to track level and use for evacuation of passengers to track level	✓				✓
(iv) Method of returning to the stowed position.	✓				✓
(v) Flood lighting & CCTV coverage of infrastructure including track, OHE & detrainment process	✓				✓
<b>TB 6 Underframe Equipment Layout Mock-up</b>					

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TB6.1 An underframe equipment layout mock-up shall demonstrate, as a minimum, the following:							
(i) Location of all equipment, and access to all mounting points.							
(a) Auxiliary Converter - inverter				✓			✓
(b) Main transformer				✓			✓
(c) Earth bar, low tension				✓			✓
(d) Earth bar, high tension				✓			✓
(e) AC control box				✓			✓
(f) CM starting box				✓			
(g) AC current transformer				✓			✓
(h) 74P Jumper coupler				✓			✓
(i) High tension connection box				✓			✓
(j) Shore power supply boxes				✓			✓
(k) Junction box, speed sensor				✓			✓
(l) ATP Antenna (BS02)				✓			
(m) Air compressor unit				✓			✓
(n) Air dryer				✓			✓
(o) Air reservoirs				✓			✓
(p) Brake control unit				✓			✓
(q) Aux. Compressor				✓			✓
(r) Valve boxes				✓			✓
(s) Battery Box				✓			✓
(t) Battery control Box				✓			✓
(u) Converter inverter (C/I)				✓			✓
(v) Electrical horn				✓			✓
(w) Flexible hoses				✓			✓
(x) Semi-permanent coupler				✓			✓
(y) HT connection layout from roof to Transformer				✓			✓
(z) Any other item as required by the Engineer				✓			
(ii) Routing of all cables including inspection covers to ensure easy accessibility.				✓			✓
(a) Cable (Flexible tube) harness duct				✓			✓
(b) Cable (Flexible tube)				✓			✓
(c) Any other item as required by the Engineer				✓			✓



(iii) Routing of all piping including isolation cocks to ensure easy accessibility and proper identification using colour coding.	✓			✓		✓	
(a) Air piping (including fitting & cleat)	✓			✓		✓	
(b) Valve pressure switch air filter	✓			✓		✓	
(c) Isolation & cut out cock, test fitting	✓			✓		✓	
(d) Any other item as required by the Engineer	✓			✓		✓	
(iv) Location of and access to all routine maintenance activities, including lubrication points, filter changes, monitoring points and pneumatic system test points.	✓			✓		✓	
(a) Oil separator	✓			✓		✓	
(b) Drain cock, drain plug	✓			✓		✓	
(c) Valve boxes	✓			✓		✓	
(d) Any other item as required by the Engineer	✓			✓		✓	
(v) Location of any skirts or covers, and access to equipment behind.	✓			✓		✓	
(vi) Labels and markings of equipment.	✓			✓		✓	
(vii) Cable layout, cleating, provision of additional cables.	✓			✓		✓	
<b>TB 7 Roof Equipment Layout Mock-up</b>							
<b>TB7.1 A roof mounted equipment layout mock-up shall demonstrate, as a minimum, the following:</b>							
(i) Location of all roof mounted equipment, and access to all mounting points.	✓			✓		✓	
(a) Pantograph & insulator			✓			✓	
(b) VCB			✓			✓	
(c) Emergency SW, Surge arrester, Potential transformer			✓			✓	
(d) Antenna, Train radio (BS-14)	✓						
(e) Air conditioner (* One HVAC unit shall be real)	✓		✓			✓	
(f) Any other item as required by the Engineer	✓						
(ii) Routing of all cables and piping.	✓					✓	
(iii) Location of and access for all routine maintenance activities, including lubrication points, filter changes and monitoring points.	✓					✓	
(iv) Location of any skirts or covers, and access to equipment behind.	✓			✓		✓	
(v) Water drainage arrangement	✓					✓	
<b>TB 8 Door Equipment Mock-up</b>							
<b>TB8.1 A fully functional mock-up for complete car having 4 doors a side, including the actual door drive, door gear, door track and door leaves complete with sealing arrangements, shall be provided. It shall demonstrate as a minimum:</b>							
(i) The door opening and closing forces and timings.	✓					✓	

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(ii) The means of adjusting them.	√					√
(iii) The means of adjusting door leaf location and travel.	√					√
(iv) Accessibility for maintenance and adjustment.	√					√
(v) Internal and external release mechanism at stations following power loss, etc.	√					√
(vi) The means of locking a failed or defective door to prevent use.	√					√
(vii) Cycling to release a trapped object.	√					√
(viii) Door status indicators (interior and exterior)	√					√
(ix) Door seals (Noise reduction)	√					√
(x) Dust protection of door machining	√					
(xi) Access to door machine	√					√
<b>TB 9 Shore Supply Mock-up</b>						
<b>TB 9.1 A fully functional mock-up for Shore Supply shall be provided. It shall demonstrate as a minimum:</b>						
	√					√

**Note**

1. The definition of the 'Type of parts used' for the manufacturing of the Mock up i.e. 'Real', 'Imitation' and 'Dummy' is as follows:-

- (i) 'Real': Real/Actual parts with full functionality.
- (ii) 'Imitation': Imitation parts with no functionality but accessibility and maintainability.
- (iii) 'Dummy': Dummy parts with no functionality and only for location identification.

2. Real parts, wherever mentioned shall be above, are manufactured with materials which have same function as mass production.

3. Imitation parts shall be manufactured with similar to real products, but can be partially different.

4. Dummy parts shall be manufactured with FRP/composite durable materials.

5. The above detailing and classification of parts to be used as 'Dummy', 'Imitation' or 'Real' is indicative. To be finalized during design stage with the approval of the Engineer.



**APPENDIX TC. ABBREVIATIONS****TC1 General**

TC1.1 Various abbreviations used in this document are set out in alphabetical order in table TC1.1

Table TC1.1 Abbreviations.

Abbreviation	Description in Full
ASHRAE	American Society for Heating , Refrigeration and Air-conditioning Engineers
ATC	Automatic Train Control (System)
ATO	Automatic Train Operation (System)
ATP	Automatic Train Protection (System)
ATS	Automatic Train Supervision (System)
BCP	Brake Cylinder Pressure
BP	Brake Pipe
CATC	Continuous Automatic Train Control
CCTV	Close Circuit Television
CCITT	Consultative Committee on International Telegraphy and Telephony
CD	Commencement date
CI	Converter Inverter
CM	Coded Manual (Driving Mode)
DFF	Direct Fixation Fastener
DIN	German Industrial Standards
DLP	Defect Liability Period
DM	Driving Motor Car
DMRC	Delhi Metro Rail Corporation
MMRTS	Mumbai Mass Rapid Transport System
EER	Energy Efficiency Ratio
EMC	Electro-magnetic Compatibility
EMI	Electro-magnetic Interference
EMU	Electric Multiple Unit Train
EP	Electro-Pneumatic
FFT	Fast Fourier Transform
FMEA	Failure Modes Effects Analysis
FMECA	Failure Modes Effects and Criticality Analysis
FRACAS	Failure Reporting And Corrective Action System
GS	Employer's Requirements : General Specification
HSCB	High Speed Circuit Breaker
HVAC	Heat, Ventilation and Air Conditioning
IC	Integrated Circuit
IEC	International Electro-technical Commission
IGBT	Insulated Gate Bi-Polar Transistor
IMP	Interface Management Plan
ISO	International Standards Organisation
kmph	kilometer per hour
LCD	Liquid Crystal Display
LED	Light Emitting Diode
LRU	Least Replaceable Unit
M	Motor Car
MCB	Miniature Circuit Breaker
MRTS	Mass Rapid Transit System
MDBF	Mean Distance Between Failures
MDBCF	Mean Distance Between Component Failures
MRTS	Metro Rail Transit System
MSS	Maximum permissible Safe Speed
MTTR	Mean Time To Repair
MWI	Maintenance Works Instruction
NFPA	National Fire Protection Association
OCC	Operations Control Centre
OCS	Over-head Catenary System



OEM	Original Equipment Manufacturer
OHL	Over Head Line
O & M	Operation and Maintenance
PA	Public Address (System)
PCB	Printed Circuit Board
PEA	Passenger Emergency Alarm
PLC	Programmable Logic Control
PSSS	Passenger Saloon Surveillance System
PWM	Pulse Width Modulation
RAM	Reliability, Availability and Maintainability
RDSO	Research Design and Standards Organisation (Ministry of Railways)
RH	Relative Humidity
RI	Ride Index
RM	Restricted Manual (Driving Mode)
SBD	Safe Braking Distance
SCS	Safety Cut-out Switch
SMD	Surface Mounted Devices
T	Non Driving Trailer Car
TCMS	Train Control Management System
TR	Train Radio
Train ID	Train Identification Number
TS	Employer's Requirements : Technical Specification
VCB	Vacuum Circuit Breaker
VDU	Video Display Unit
VVVF	Variable Voltage Variable Frequency
ZVR	Zero Velocity Relay



**APPENDIX TD. INTERFACES BETWEEN ROLLING STOCK, SIGNALLING AND TELECOMMUNICATION CONTRACTORS**

**TD.1. INTRODUCTION**

**TD1.1 Definitions and Scope**

TD1.1.1 This Appendix describes the interface requirements between Contract MRS1, Rolling Stock Contract for Line 2 and 7 of Mumbai Metro and contracts for Signalling and Train Control, Contract for Line 2 and 7 and also with, Telecommunications Contract for Mumbai Metro.

TD1.1.2 The Contractors as above shall ensure that all requirements of the Specification pertaining to interfaces are properly satisfied. There is possibility of having multiple Contractors for signalling and telecom. RS Contractor shall interface accordingly with more than one signalling /telecom and any other designated Contractor.

TD1.1.3 The Rolling Stock Contractor shall provide equipment, software, functionalities etc. of Train to meet the requirement of Interface. Signalling & Telecommunication Contractor shall provide on board equipment, software, functionalities etc. of S&T, and ground equipment, software, functionalities etc. to meet the requirements of interface. The requirements specified herein are by no means exhaustive and it remains the responsibility of the Contractors to develop and execute an interface plan during execution of the work to ensure that:

- (i) All interface issues between the different contracts are satisfactorily resolved
- (ii) Supply, installation and testing of equipment and software are fully co-ordinated
- (iii) All equipment supplied in the contract are fully compatible with each other
- (iv) UTO mode of operation is achieved with all its inherent features.

TD1.1.4 The Automatic Train Protection (ATP) system shall issue the braking commands to the Rolling Stock when safety limits are exceeded or when over-speed is detected. The removal of traction power and the correct application of brakes shall be the responsibility of Rolling Stock Contractor. The ATP system shall be responsible for monitoring of speed and the issuing of braking commands when safety speed limits are exceeded.

TD 1.1.5 Parking brakes shall be provided by the Rolling Stock Contractor. The parking brakes shall be capable of holding a fully loaded stationary train on a 4% gradient under all track conditions, indefinitely.

TD 1.1.6 There shall be two stage commissioning. In the first stage, the train operation shall be by single Train Operator. In the first stage ATP/ATO/RM/ROS/Cut-out modes described below will be made available. In the second stage UTO and associated modes viz standby mode etc. will be commissioned.

**TD 1.1.7 Interface Management**

TD1.1.7.1 Each contractor shall establish a structured process to integrate with other E&M systems to ensure safe, reliable and efficient operations under both normal and degraded conditions to the satisfaction of the Employer's Engineer.

TD1.1.7.2 Each contractor shall ensure that the equipment supplied under this Contract are properly interfaced and integrated with other systems in Mumbai Metro.

TD1.1.7.3 Each contractor shall appoint competent and experienced person (Interface Manager), with no fewer than 5 years of similar railway project experience who shall be the single point of contact for all interface design and testing works with the interfacing contractors and the Employer's Engineer.

TD 1.1.7.3.1 Full time mobilization of 'Interface Manager (IM)' at site shall be done by RS as well as Signal Contractor within three (3) months of the commencement date. Non mobilization of the 'Interface Manager (IM)' within the stipulated three months would attract penalty (to be solely finalized by the Engineer) for delay of each month or part thereof. The penalty amount shall include the consequential loss on account of non-availability of an approved and experienced 'Interface Manager (IM)'.



- TD 1.1.7.3.2 All Interface Meetings, unless specifically approved by the Engineer shall be held at site and Engineer's representative shall be given sufficient notice to attend the meeting.
- TD1.1.7.4 Each contractor shall be responsible for interface identification, establishment, construction and testing works either in the capacity as the Lead Contractor or Participating Contractor.
- TD1.1.7.5 Signalling Contractor shall be the Lead Contractor. The Lead Contractor will be responsible to initiate, plan, coordinate and produce jointly with the Participating Contractors all the required interfaces and interface design documents and interface progress reports for submission to the Engineer for acceptance. The Lead Contractor will also prepare and issue all interface meeting minutes after incorporating RS Contractor's comments within 3 days of the meeting and provide bi weekly interface progress reports to all the participating contractors for information.
- Later, forwarding of issued minutes of meeting and bi weekly interface progress reports to respective Engineers shall be responsibility of concerned Contractors.
- All the participating contractors shall ensure that copy of the Interface design documents submitted to the Engineer of the Signaling contractor shall also be submitted to their respective Engineer required to participate in the Interface Meetings.
- TD1.1.7.6 Rolling Stock, PSD and the Telecommunication Contractor will be the participating contractors. The Participating Contractors shall collaborate fully with the Lead Contractor in the development and finalization of the interface design, joint production of the interface documents and interface progress reports.
- TD1.1.7.7 The costs for all interface design and testing works shall be deemed to be included in the Contract sum regardless of the actual extent of effort required or expended by the Contractor.
- TD1.1.7.8 The Contractors shall be fully responsible for the management and control of his sub-contractors in relation to all interfacing activities carried out under the Contract.
- TD1.1.7.9 Deleted.
- TD1.1.7.10 The Signalling Contractor shall provide necessary support to resolve all pending or new interface related issues arising during the operation of the trains till completion of Rolling Stock defect liability period. The Rolling Stock Contractor shall provide necessary support to resolve all pending or new interface related issues arising during the operation of trains till completion of Signalling defect liability period. It shall also be noted that changes in the interface specifications such as key alarms, remote commands, interface signals and GUI specifications are to be expected throughout the project execution stage and shall extend up to 6 months after commencement of UTO operation based on operational requirements.
- TD 1.1.7.11 Rolling Stock Contractor shall be responsible for development of the GUI (including hardware) for the RS Controller (RSC) in the OCC (Operation Control Centre)/BCC (Backup Control Centre). Any other GUI(s) in OCC/BCC shall not be the scope of RS contractor. Total number of the distinctively different screens with live buttons may be around ten.
- TD 1.1.7.11.1 Lead contractor shall ensure suitable connectivity between the workstations of the Traffic Controller, RS Controller, CCTV and others as finalized during interface design.
- TD 1.1.7.12 Lead contractor shall provide server for CCTV in the OCC/BCC. RS Contractor shall provide server for TCMS data in the OCC/BCC. These servers shall be networked with the depot server of the RS contractor. All the requirements of server/buffering to be done on the train for live streaming of video shall be the responsibility of RS Contractor.
- TD 1.1.7.13 Lead contractor shall be responsible for enabling and implementing any addition/ deletion of the alarms from the trains to OCC and remote commands from the OCC to train throughout the project execution stage including up to 6 months after commencement of



- UTO operation, as advised by the RS Contractor/Engineer. Separate set of alarms and commands may be required to be reported/executed from the Traffic controller and the RSC workstations. RSC workstation shall be the responsibility of RS Contractor.
- TD 1.1.7.14 Adequate number of workstations (minimum 4) as decided during the Interface finalisation shall be provided in OCC by the lead contractor for passenger communication with OCC on invoking of PAD (Passenger Alarm Device).
- TD 1.1.7.15 In the event of invoking of the PAD, automatic pop up of image from the relevant cameras shall be ensured in the OCC on the Large Video Screen (LVS), screens of traffic controller and RSC. RS Contractor shall interface with Lead Contractor for invoking of CCTV images on RSC workstation.
- TD 1.1.7.16 Signalling Contractor shall be responsible for free supply of cables, duly harnessed for connection of the On-board signal equipment. RS contractor shall be responsible for providing the cables for the train lines and/or Ethernet links required by the Signalling contractor. The Rolling Stock Contractor shall ensure the availability of adequate no. of train lines/ethernet considering the requirement of Signalling Contractor, which shall be discussed and finalized during interface. RS contractor to ensure that adequate number of spare train lines (minimum 10% for each type) shall be available at the end of the DLP. Signaling Contractor shall certify relevant connections, cables to on-board signaling equipment after their assembling in first train at RS contractor's premises.
- TD 1.1.7.17 Deleted.
- TD 1.1.7.18 Deleted.
- TD 1.1.7.19 Lead contractor shall be responsible for providing suitable communication link for live streaming via CCTV network from TCMS to OCC/BCC and for live transmission of the advertisements or other data via CCTV network from OCC/BCC to TCMS. The live video stream transmitted from the train to the OCC/BCC shall be suitably buffered for its onward multicast transmission to other terminals/networks. This buffering arrangement in OCC/BCC via CCTV server shall be responsibility of Lead Contractor. For live video stream from OCC/BCC to train, the buffering on the train shall be responsibility of RS Contractor. The Rolling Stock Contractor shall provide Live Video Players with buffering capability. The RS Contractor shall also provide the advertisement and live video players in hot standby pair per train. The RS Contractor shall also provide redundant suitable arrangement (video controller/player/servers) in OCC/BCC for transmission of live video contents and stored video contents to be played in the train.
- TD 1.1.7.20 The contractors shall ensure that all the requirements of the Metro Railway General Rules are duly met by incorporating appropriate alarms, remote commands and other features.
- TD 1.1.7.21 Lead contractor in close coordination with the RS contractor shall ensure that the ATO/UTO modes of operation designed are optimized for least energy consumption.
- TD 1.1.7.22 It is expected that complete duplication of the TCMS VDU screen with live buttons for executions the requisite commands shall be available on demand in the RSC workstations.
- TD 1.1.7.23 Lead contractor's scope shall be limited to provide Access Point for enabling remote download of TCMS/CCTV data through CBTC/CCTV network. Scope of server along with data bank shall be of RS contractor. This clause shall be read in conjunction with sub-clause TD 3.1.21 of this document.
- TD 1.1.7.24 Both lead as well as RS contractor shall ensure that complete and detailed log of the signals exchanged between VATC and TCMS shall be retrievable on demand for diagnostics.
- TD 1.1.7.25 Interface shall be done to achieve stabling of trains in depot based on corrective and preventive maintenance scheduling to be provided by RS Contractor to Lead Contractor. Lead contractor shall ensure seamless dynamic interface with the outputs of the Depot Maintenance Software package.
- TD 1.1.7.26 Lead contractor shall be responsible for slow speed movement on the Automatic Wash Plant (AWP). Interface will be required to be done with the AWP supplier for ATO/UTO modes. RS Contractor shall provide wash mode facility for other manual modes like ATP/RM/ROS/Cutout.



- TD 1.1.7.27 Emergency brake application validation at slow speed (less than or equal to 25 kmph) shall be achieved as a part of the wake up procedure as finalized by the lead contractor.
- TD 1.1.7.28 Lead Contractor to ensure that in the event of deflated condition detection or otherwise, the maximum speed shall not exceed the stipulated speed under such condition as advised by the RS Contractor. This information shall be provided by RS to Lead Contractor on board in a safe manner.
- TD 1.1.7.29 Lead contractor shall provide location information to the RS Contractor. RS Contractor shall use the same for different distance based algorithms provided in the RS.
- TD 1.1.7.30 There shall be a provision for transfer of train operation data in the problematic train on main line to the Roving Attendant Maintenance Terminal at the end of the trip of the train for troubleshooting and analysis purpose. The Roving Attendant Maintenance Terminal and facility to transfer train operation data from problematic train to the Roving Attendant Maintenance Terminal shall be provided by RS Contractor. The RS Contractor must interface with the Signaling Contractor so that this transfer of train operation data to Roving attendant terminal shall not result in CBTC and CCTV communication disruption.
- TD 1.1.7.31 Ground based hot axle box detection for monitoring of axle box temperature shall be provided by Rolling Stock Contractor. The ground equipment shall be provided by RS Contractor. The server in OCC, required software and communication network from way side equipment up to station Telecom Equipment Room (TER) shall be provided by RS Contractor. The Telecom Contractor shall provide Ethernet channel from station TER (Telecom Equipment Room) to CER (Central Equipment Room) of OCC. Data processing, interface equipment on both ends i.e. at wayside station and OCC shall be responsibility of RS Contractor.

## TD2 TRAIN OPERATING MODES

### TD2.1 General System Description

- TD2.1.1 The train-borne Automatic Train Control (ATC) system will consist of Unattended Train Operation (UTO), Automatic Train Operation (ATO) system and Automatic Train Protection (ATP) on Line #2 and Line#7 of Mumbai Metro.
- TD2.1.2 The Rolling Stock required for these lines shall be fitted with ATP/ATO/UTO system. The UTO system shall conform to Grade of Automation 3 (GoA3) and Grade of Automation 4 (GoA4) as defined in IEC 62290-1 2006.
- TD2.1.3 The Automatic Train Control (ATC) System shall be supplied by the Signalling Contractor, who shall be required to liaise closely with the Rolling Stock Contractor, in regard to the installation, testing and commissioning of the Signalling and Train Control Equipment.

### TD2.2 Unattended Train Operation- (UTO Mode)

This mode consists of full driverless unmanned operation and shall be the default mode at stage 2 of commissioning unless exceptional circumstances occur. Train shall be operated unmanned or with attendant under fully automated GoA3 and GoA4 mode. This mode shall be available everywhere on the line and the depot except for the workshop lines. Details shall be finalised during interface and design finalization.

### TD2.3 ATO Mode

- TD2.3.1 The onboard equipment shall provide for Automatic Train Operation (ATO) on Line #2 and Line#7. In this mode, the train's speed, motoring, coasting and braking within the parameters dictated by the ATP system shall be performed by the on-board equipment without the train operator's intervention. This operation shall include:
- (i) Automatic operation of trains between stations.
  - (ii) The ATO system shall provide control for acceleration, deceleration and coasting of trains in such a manner that the specified schedule speed is achieved with minimum energy consumption. ATO shall also provide "All-Out Mode" of train operation to make up time loss to the extent possible by reducing the coasting period, in case train is not running in accordance with Time-Table.



- (iii) Receipt of coasting request and passing of request to traction power equipment and also provide for acceleration and deceleration of the train.
- (iv) Automatic stopping of trains at platforms within a tolerance of  $\pm 300\text{mm}$  for 99.98% of station stops.
- (v) Automatic opening of doors on the appropriate platform side(s) when the train is berthed.
- (vi) Prevent the train from starting if train doors are detected "not closed".
- (vii) Receipt and implementation of control to skip one or more stations.
- (viii) CBTC system shall allow a train to enter a station platform only if the preceding train has a movement authority that shall allow it to fully leave the platform area and it has begun to move out of the station (i.e., within ATP constraints, train movement shall be controlled to minimize the likelihood of the train coming to a stop when only partially within the station platform limits).

The trains under ATO operation shall always remain under ATP protection. Transfer from ATP to ATO mode shall only be possible at standstill at a station stopping point, however transfer from ATO to ATP mode shall be possible at any time.

- (ix) It shall be possible for train operator to close the doors and start the train in ATO mode even before dwell time at less crowded stations.

TD2.3.2 The ATO mode shall include Automatic Turnback at the terminal stations including the intermediate turnback stations. The Automatic turnback facility will be without driver and shall be provided at (a) platform of the terminal station (b) turnback track at rear of the terminal station (c) platform of intermediate turnback station.

#### TD2.4 **ATP (or Coded Manual) Mode**

TD2.4.1 The onboard equipment shall provide Automatic Train Protection (ATP) on all lines/ sections. In this mode, the train operator shall perform the control of the train speed and braking within the parameters dictated by the ATP system.

TD2.4.2 The ATP mode shall include:

- (i) Identification and enforcement of maximum speed at which the train may operate, shall be in accordance with the safe speed of 90 kmph.
- (ii) Identification and display of actual speed, target speed, target distance, and the operating speed.
- (iii) Identification and audio-visual warning when train is operating at a speed higher than the maximum safe speed. The equipment to provide audible and visible warnings shall be provided by respective Signalling and Train Control Contractor.
- (iv) Provision of an audio-visual warning to the train operator, when the system identifies that the train is operating at a speed in excess of the maximum safe speed; recognition of a delay of 2s for the train operator to react, and a service brake application should the train operator fail to reduce the speed below the maximum safe speed in a specified time. In the event of the service braking rate being inadequate, an irrevocable Emergency Brake application shall be made, automatically.
- (v) Identifying the platform side of the train with the train berthed at a station. The system shall then enable the doors to be opened on that side.
- (vi) Receipt of a door closed signal indicating that all doors are closed and locked before the train may start. Loss of this signal shall cause the ATP system to initiate a brake application.

#### TD2.5 **Restricted Manual (RM) and Run on Sight (ROS) Mode**

TD2.5.1 In RM mode, the maximum train speed shall be controlled by the on-board ATP, to a limit not exceeding 25 kmph. This mode shall be available only when the on-board ATP equipment is operational.

TD2.5.2 ROS mode of operation shall be selectable by suitable means. In this mode, the maximum trains speed shall be controlled by the on-board ATP, to a limit not exceeding 25km/h. This mode shall be available only when the on-board ATP equipment is operational. The running



monitoring shall be the same as for RM. The ATP shall give cab signal indications as soon as the train reaches a track position where normal running can be resumed. The ATP authorizes the ROS request.

TD2.6

**Cut-out (or By-pass) Mode**

TD2.6.1

By-pass Mode shall be provided for use in the event of failure of the ATP system. In this mode, the train speed shall be controlled entirely by the train operator, to a limit adjustable between 15 kmph and 25 kmph. RS Contractor shall provide equipment and means to ensure that the maximum train speed remains within the above limit when the Cut-out Mode is in effect, under all circumstances.

TD2.6.2

The ATP By-pass Mode shall be initiated by the train operator operating a sealed Safety Cut-out Switch (SCS) and simultaneously breaking its seal. The operation shall be recorded by the on-board digital counter and TCMS. The SCS shall be provided by RS Contractor. The on-board digital counter shall be provided by the Signalling Contractor. In this mode, the train doors shall only be enabled and controlled manually.

TD2.6.3

The availability of power supply to the ATC system during this mode will be decided during the design finalization.

TD2.7

**Standby Mode (ready, dozing, sleeping), Immobilized mode etc.**

A fully initiated train in standstill condition. Traction control shall be inoperative and brake shall be applied during this mode. The details of the mode will be finalised during design stage.

TD2.8

**Identification: Train Operating Mode, Train Description and Next Station Information**

TD2.8.1

Signalling Contractor shall provide a four digit Train Identification Number (Train ID) to RS Contractor. The first two digits shall identify a destination while the second two digits shall be a service identifier. RS Contractor shall accordingly use the relevant information such as names of intermediate stations, stopping pattern, station stop door opening side information, skipping station information, keep door closed information, train going to depot information etc. for operation of on-train systems.

TD2.8.2

Train ID shall be allocated to train at suitable place and shall be maintained until it finishes its service. It shall be possible by the Employer to amend and / or modify the Train ID, subsequently, to suit the operational requirements. The Signalling and Train Control, and Rolling Stock Contractors shall provide necessary equipment and means for the same. Rolling stock contractor shall provide suitable arrangement for Train Operator to view this information displayed on the Train information panel provided on front and other display information inside the train from his seat.

TD2.8.3

RS and Signalling contractors shall exchange information identifying the effective mode, the active or non-active status of each cab, the door status etc. The inputs shall be categorised as vital and non-vital. The levels and form of these inputs shall be coordinated between the two Contractors.

TD2.8.4

RS Contractor shall provide necessary inputs to the Telecommunications Contractor identifying the required mode and status of active cab etc. The levels and form of these inputs shall be coordinated between the two Contractors.

TD2.8.5

RS Contractor shall log each time the mode is changed using the onboard TCMS equipment.

TD2.8.6

In By-pass/ Cut-out Mode or any other mode, external indication light shall flash or occult which will be finalized during design stage.

TD2.8.7

Signalling Contractor shall provide the necessary input signals (next station information code, platform side information, triggering signal, etc.) to Rolling Stock for displaying and making next station announcements to passengers on-board. RS Contractor shall provide the necessary hardware. Levels and protocols shall be agreed between the contractors.

TD2.8.8

For UTO/ATO operation, the necessary train command digital inputs signals shall be provided by the Signalling Contractor. The ATP/ATO/UTO initiated signal demands shall be redundant. The redundancy shall also be provided on TCMS side by RS Contractor. The form of these inputs shall be coordinated between RS and Signalling contractors.



- TD3. INTERFACE REQUIREMENTS BETWEEN SIGNALLING, TELECOMMUNICATION AND RS CONTRACTORS**
- TD3.1 General**
- TD3.1.1 Signalling and Telecommunication Contractors shall provide RS Contractor with the final list of equipment to be provided on the Rolling Stock. The sizes and weights of the UTO/ATO/ATP and radio on-board cab equipment and antennae etc. to be mounted on the Rolling Stock shall also be provided, as applicable. The location of the onboard cab equipment shall be mutually agreed between Signalling and Rolling Stock Contractors so as to optimize seating & standing space duly considering maintainability and easy accessibility, however the onboard cab equipment shall not be placed in the underframe on account of maintainability issues.
- TD3.1.2 Signalling and Telecommunication Contractors shall deliver to the RS Contractor's factories, all train-borne ATC and radio equipment, as applicable, and data to enable fitting and testing.
- TD3.1.3 Signalling Contractor shall supply at RS Contractor's factory pre-wired equipment racks with appropriate connectors for all wiring terminating inside ATC, including wiring between ATC racks. Telecommunication Contractor shall similarly supply all the train radio equipment including the Train Radio Control Panel at the RS Contractor's factory. Signalling and Telecommunication Contractors, with the details provided by RS Contractor shall ensure that the exterior finish and colours of the respective equipment suitably harmonize with that of the cab and the vicinity.
- TD3.1.4 Interfacing wiring for each module provided by Signalling and Telecommunication Contractors including the interfacing wiring between Signalling and Telecommunication Contractors' equipment shall terminate in a quick disconnect robust plug connector suitable for traction applications, with direct cable connection as far as possible. All cable connectors shall be identified within the cubicle using robust cable markers with distinctive colours for identification of e.g. safety function cables.
- TD3.1.5 For all relay contact interfaces Signalling and Telecommunication Contractors shall provide auto-contact jam detection and contact bounce elimination function to ensure proper operation of the system. Relays for safety functions shall comply with the appropriate internationally accepted standard specification.
- TD3.1.6 Signalling and Telecommunication Contractors shall provide RS Contractor with the number of wires and/or Ethernet connections required between cars of a married pair and between married pairs to transmit signals from one end of the rake to the other end. The coupler status shall be transmitted to the Lead Contractor in fail safe manner. Provision of redundancy and spares shall be catered for by RS Contractor for Train lines and/or Ethernet connections.
- TD3.1.7 For compatibility, the Rolling Stock and the train detection system (track circuits/axle counters), shall conform to EN 50238.
- TD3.1.8 Vehicle control circuits shall be developed by the RS Contractor. During the design stage, all the vehicle control circuits incorporating the identified interfaces shall be provided to Signalling and Telecommunication Contractors, as applicable. Signalling and Telecommunication Contractors shall provide specific observations on these circuits to RS Contractor. RS Contractor shall suitably incorporate these observations in the design.
- TD3.1.9 Screened cables for train borne signaling equipment shall be properly terminated so as to ensure that no return loops are formed to cause electrical noise.
- TD3.1.10 Train No. between the two systems shall be so designed so as to ensure that requisite information of train / car/ATC/ destination etc. is captured.
- TD3.1.11 Both Signalling and Rolling Stock Contractors to ensure that all input and output signals exchanged between rolling stock equipment and on-board signaling equipment shall be recorded and shall be available for retrieval on demand for analysis / record. All signals (import/export between RS & Signalling) shall generally be routed through TCMS.
- TD 3.1.12 Rolling Stock Contractor to ensure that all doors related and other safety / train control related signals including brakes, position of safety cut out switches, direction related relays, suspensions, obstruction on track etc. are communicated to the Signaling Contractor.



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- TD 3.1.13 Signaling Contractor to define as a part of interface the signals that will be provided by signalling train borne equipment.
- TD 3.1.14 Provision of "Jog and Creep mode" operation with command to operate the train at specified reduced speed under degraded condition (e.g. aligning train in case of undershoot/overshoot of Normal Stopping Point within a limit) shall be addressed in the interface.
- TD 3.1.15 The Rolling Stock Contractor and Signaling Contractor will jointly finalize a list of actionable command and responses for UTO mode of operation which shall be available at Central Automatic Train Supervision (CATS) system at OCC as well as Local Automatic Train Supervision (LATS) system at Station Control Room (SCR). The two Contractors shall also finalize the list of alarms and events for Rolling Stock monitoring and troubleshooting which shall be displayed on the Rolling Stock Controller monitor of CATS system at OCC as well as on other suitable terminals in depot and on the line.
- TD 3.1.15.1 The key alarms, which are related to the events of operation, safety etc. and critical/serious in nature shall be displayed to both Traffic Controller as well to Rolling Stock Controller. All other alarms and events shall be displayed to Rolling Stock Controller.
- TD 3.1.15.2 The list of alarms, events and remote control commands shall be proposed by Rolling Stock Contractor and approved by the Engineer. The implementation of alarms, events and remote control commands shall be ensured by both the Contractors. The packet size should have margin to accommodate additional requirement for future.
- TD 3.1.15.3 The Engineer shall be able to add/delete/modify the alarms, event and remote command up to 6 months after commencement of UTO operation. Necessary training and hands-on shall be provided during execution of project.
- TD 3.1.16 Rolling Stock shall propose a user friendly Graphical User Interface (GUI) for RS Controller in the form of a conceptual schematic/wireframe that shall include page layouts, arrangement of the GUI's content, interface and navigational elements, and a description of how they work together. The features of Rolling Stock Controller GUI shall be as under:
- TD 3.1.16.1 RS Controller GUI shall have the capability to monitor the information of all trains within the network. The GUI shall employ different colors for highlighting different status of trains. The status of various subsystems, MCBs, Relays & Switches, Train Lines shall be displayed on GUI and it shall be possible to acknowledge faulty trains immediately. It shall be possible to identify cause of events/Alarms on GUI.
- TD 3.1.16.2 The GUI shall make available both current faults and historical fault records with provision of sorting and filtering the list.
- TD 3.1.16.3 There shall also be a provision to request on-board TCMS VDU screen on demand for display on RS controller screen with automatic refresh periodically not more than 1 second, with navigation feature and actionable button.
- TD 3.1.16.4 A user friendly Troubleshooting Directory (TSD) shall also be made available in RS Controller GUI.
- TD 3.1.16.5 The GUI shall also make available remote control commands via clickable screen button elements that shall be visibly different from non-clickable icons/shapes. Remote control commands from RS Controller GUI shall be additional to the commands from CATS/LATS.
- TD 3.1.16.6 The screen elements shall be dynamic dropdown menus to make optimum use of screen area.
- TD3.1.16.7 Train Operation Data (TOD) shall contain train status data and faults/alarms/information etc. to be displayed on the RS Controller console. The Signalling Contractor shall ensure that sufficient margin in the data packet size have been kept and the bit mapping of the packet contents are easily editable independent of the ATS software. The TOD shall have a refresh rate of minimum 1 second.
- TD3.1.17 Rolling Stock Contractor shall provide CCTV cameras in the train which will cover cab, saloon, front of train, rear view camera, area for passenger initiated alarm, detrainment door etc. The CCTV cameras shall provide for minimum 24 hrs. of recording onboard. Rolling Stock Contractor and Signalling Contractor shall interface for control and data transfer of CCTV images from the train to OCC/SCR on the ATS terminal and Large Video



- Screen. The hardware interface shall be furnished and installed by RS Contractor. The CCTV signal shall be provided by RS Contractor at a suitable port on board to Signalling Contractor for transmission to OCC/BCC. There shall be no processing of CCTV data by S&T Contractor. At OCC/SCR it shall be possible to select any camera onboard and view the recording live at any terminal/workstation. The Levels and protocols shall be agreed between the two contractors.
- TD3.1.18 The CCTV server shall be provided in OCC and BCC by Signalling Contractor. The Signalling Contractor shall interface with Rolling Stock Contractor for correct assessment of storage of all camera images or a fisheye camera to have virtual view of required area. Facility to transfer historic data (5 min pre and 15 min post recorded CCTV feeds) on demand from train to OCC/BCC manually shall also be possible from OCC/BCC.
- Necessary provision in terms of playing the historic data in OCC/BCC along with sufficient storage capacity of 2 TB shall be ensured in CCTV server.
- Provision shall also be made to retrieve all historic data of last 7 days in one go from CCTV Server at OCC/BCC. The CCTV recordings 5 minutes prior and up to 15 minutes after the event shall be so stored that these are retrievable as a single data file for each event.
- TD3.1.19 CCTV image feed received in OCC/BCC shall support buffering with 10 min pre data stored on memory cache of CCTV server. The GUI for viewing CCTV images shall support rewinding the images up to 10 min before real-time.
- TD 3.1.20 Rolling Stock and Signalling Contractors shall interface to ensure that at least but not limited to following emergency conditions should result in the event based auto popup of CCTV images via CCTV network on RS Controller Terminal. The detail implementation shall be finalized during interface with the approval of Engineers. The utilization of bandwidth of CCTV network shall be managed dynamically.
- PAD activation
  - Detrainment Door Activation
  - ODD activation
  - Side Door Obstacle detection
  - Fire/Smoke Detection
  - CCTV Emergency Button Activation
  - Driving console cover open
  - ADD (Auto-Dropping Device)/track/catenary/infrastructure related events etc. (Refer ERTS Clause 12.2.1(B)(k)).
- Transfer and display of such images from CCTV Server to LVS and Traffic Controller work stations shall be responsibility of Lead Contractor for which RS and Lead Contractor shall interface.
- TD 3.1.21 In depot, Train diagnostic data and CCTV images shall be transmitted over CCTV network from train to the servers in the depot to be provided by Rolling Stock contractor. The sufficient CCTV antennas, bandwidth, network etc. shall be provided by signaling contractor.
- TD 3.1.22 Rolling stock contractor shall make provision CAT7 or latest cable/Optical Fiber, power supply and space & bracket for mounting of Wi-Fi antennas & equipment in the train for Wi-Fi facility for passengers. The equipment for Wi-Fi in the train such as antennas, servers, etc. shall be supplied by Wi-Fi Contractor.
- TD 3.1.23 The Rolling Stock Contractor shall provide necessary signals to the Signalling Contractor for proper functioning of Platform Screen Door (PSD). The Rolling Stock and Signalling Contractor shall interface for exchange of signals and develop protocol for proper working of Platform Screen Door (PSD).
- The Rolling Stock Contractor shall interface with PSD Contractor. Rolling Stock contractor shall provide KE and door drawings of train to PSD contractor for placement of Platform Screen Doors and shall share the location of Emergency Rescue Device (ERD)/Emergency

Access Device (EAD) and parking brake release lever with the Signalling Contractor and also their operating mechanism. The RS Contractor shall also interface with PSD Contractor for synchronization of Train door/PSD opening and closing and for access of PSD Local Control Panel from train operator side.

Rolling Stock, Signalling and PSD Contractors shall exchange the defective/Isolated train door and PSD door information so that if a particular train door is defective/isolated, the corresponding PSD shall not open and vice versa. Also, Rolling Stock, Signalling and PSD Contractors shall interface for provision of reclosing the door(s) without opening all doors in case of obstruction detection.

- TD 3.1.24 There shall be 4 separate radio systems for communication between Train and wayside. The system will broadly cater to Train Radio traffic, CBTC traffic, CCTV traffic and Wi-Fi traffic. The details of sharing of the 4 radio systems for sending control and data information, levels and protocols thereof, will be jointly agreed by Signaling, Telecom, Rolling Stock Contractor and Wi-Fi Contractor. The radio system for Train Radio traffic shall be provided by the Telecommunication Contractor while the radio system for sending CBTC, CCTV and other data pertaining to passenger voice, control, alarm, events etc. shall be provided by the Signaling Contractor including on-board equipment.
- The bandwidth allocation on CCTV network shall be dynamically managed. Detailed proposal for the same shall be submitted by Signaling Contractor for Engineer's review and approval.
- TD 3.1.25 Interface plan to address the procedures to be adopted for rescuing the immobile train on line by coupling the failure train with healthy train and clearing the line in Pull/Push mode with healthy train.
- TD3.1.26 Integrated Testing and Commissioning:  
The Rolling Stock, Signaling, PSD and Telecommunication Contractors shall perform Integration Test and the tests shall include but not limited to traction and braking control, precision stopping, turn back, jog function, door operation, PSD, train wake up and PA/PIS functioning test, remote command & control for Rolling Stock monitoring & troubleshooting from OCC to train and safety related test etc. All contractors shall jointly produce a protocol document for Integrated Testing and Commissioning.
- TD3.1.27 The Signaling Contractor as a Lead Contractor shall prepare a comprehensive Operating Modes and Principle Document (OMPD). The Rolling Stock Contractor, PSD Contractor and Telecommunication Contractor will assist the Signaling Contractor in preparation of the document. The traction and Tunnel Ventilation Contractors will also assist the Signaling Contractor in preparation of the documents. Employer will provide necessary inputs such as standard operating procedure. The document shall establish the principles related to system and interface design under normal, degraded and emergency modes of operation. For each operating principle, the document shall describe the scenario, action to be taken by operator and system in a structured process flow chart. The additional requirement generated while preparing OMPD document shall be treated as the requirement within the contract without any cost implication.
- TD3.1.28 The Rolling Stock Contractor and Signaling Contractor(s) shall implement automatic 'sleep', 'wake-up', 'testing and dispatch etc. (pertaining to UTO mode of operation)' of trains stabled at depot/siding/main line. Rolling stock will send suitable signal through signaling interface for display of indication and alarm at OCC/SCR/DCC level.
- TD3.1.29 Train Event Recorder shall be provided by the RS Contractor, designed to resist tampering, that monitors and records data on train speed, direction of motion, time, distance, throttle position, brake applications and operations (including service brake, emergency brake) equipped, cab signal aspect(s) etc. Signaling Contractor shall provide the requisite signal to RS for the storage purpose.
- TD3.1.30 In case of resumption of traction supply after failure/otherwise and when number of trains are standing in the section, ATS shall be capable of issuing sequential/staggered power on command and sequential/staggered starting of the train to avoid overloading of the traction supply.
- TD3.1.31 The Signalling Contractor shall provide trigger command for Neutral Section Detection, the requirement for the trigger points/locations shall be shared by Rolling Stock Contractor with Signalling Contractor. In manual mode like Cut out/RM/ROS/ATP modes, Rolling Stock Contractor shall generate a trigger command.



TD3.1.32 The continuous train location information also shall be communicated from Signalling to Rolling Stock.

### TD3.2 Rolling Stock Characteristics to be used by Signalling Contractor

TD3.2.1 The signaling system will work on moving block principle and the system shall be so designed to meet the headway requirements of 6-car trains, based on the characteristics of the vehicles to be furnished (Annexure 1/TD) and the track geometry. The back-up (line-side) signaling (in ROS/RM/cut-out mode) shall use the same track circuits/axle counter as designed for the ATP working. RS Contractor shall provide traction and braking characteristics of the actual vehicles and Signalling Contractor must co-ordinate with RS Contractor to fine-tune the system design based on the traction and braking characteristics of the actual vehicles furnished. Acceptance tests of the signal system will use the actual vehicles supplied. Brake capacity of the Rolling Stock shall be used optimally to ensure its maximum utilization when full brake equipment is operational. In case of isolation of any brake system or bogie/car, Rolling Stock Contractor shall furnish requisite information to Signalling Contractor. However, Guaranteed Emergency Brake Rate (GEBR) shall never be compromised.

TD3.2.2 When operating in ATP Mode, a delay of 2s (programmable) shall be provided for the Train Operator to acknowledge a reduction in speed and begin to apply the brakes.

TD3.2.3 The model for calculating the Safe Braking Distance (SBD) shall identify and take into account various system's response times and Train Operator's reaction times and shall be in accordance with IEEE 1474.1 standard. The design of CBTC system shall also take into account the effect of track geometry on the traction and braking characteristics. The RS Contractor shall furnish the guaranteed braking rate at the normal braking efficiency, including brake deterioration to Signalling Contractor. RS Contractor shall also provide the speed/acceleration curves and speed/tractive effort curves, for all loading conditions.

TD3.2.4 RS Contractor shall furnish as a minimum the Rolling Stock parameters to be used by Signalling Contractor for designing the CBTC system, as set out in the attached Table no. TD.1. RS Contractor shall also furnish a reasonable tolerance band for the identified performance parameters. RS Contractor shall ensure that all the trains supplied perform within the tolerance band.

TD3.2.5 For any other information required by Signalling Contractor, he shall co-ordinate with RS Contractor.

TD3.2.6 The Rolling Stock Contractor and the Signalling Contractor shall share all the interface signals and shall log /record these signals/data by either of them.

TD3.2.7 The Rolling Stock Contractor shall provide optimized energy efficient run curve pattern to Signalling Contractor for incorporation in the ATO/UTO mode of operation. All associated information as requested by Signalling Contractor shall be duly handed over by Rolling Stock Contractor. The efficacy of the finalized run curves shall be jointly demonstrated by means of simulations as well as line trials.

Optimization of energy efficient mode shall consider different TE (Tractive Effort) /BE (Braking Effort) curve for different loads as well. Contractor shall demonstrate optimization of energy with respect to different TE (Tractive Effort) /BE (Braking Effort) curve for different loads.

### TD3.3 Signalling and Telecommunication Details to be used by RS Contractor

TD3.3.1 The following data shall be provided:

- (i) The maximum power consumed by Signalling and Telecommunication Contractor's equipment from the 110V DC supply under all specified operating conditions.
- (ii) The number of train wires/ Ethernet connections required, and the function of each.
- (iii) All control logic outputs.
- (iv) Electrical characteristics of the interconnection cabling and wiring.
- (v) Sensitivity levels, and frequencies which must be avoided.
- (vi) The specific heat load for air conditioning purposes.



- (vii) The EMC /EMI requirements including the limiting value of psophometric current, to obviate interference in the operation of telecommunication equipment
- (viii) Details of the provisions required to enable the bidirectional transference of data from the train to the wayside.

### **TD3.4 ATC and Radio Equipment Cubicles**

TD3.4.1 RS Contractor shall supply the ATC and Train Radio equipment cubicle enclosure(s). All supports, braces, mounting holes, cabling apertures, etc. required for mounting the cubicle and its equipment shall be properly coordinated between Signalling and Telecommunication Contractors and RS Contractor to ensure secure mounting, and access. The cubicle(s) shall be resiliently mounted. For housing of ATC and active Radio equipment, suitable enclosed environment (minimum IP-52) needs to be provided by the RS contractor.

TD3.4.2 To achieve the ATC control functions, Signalling Contractor shall identify any interfacing circuits specifically required for ATC operation and liaise with RS Contractor. These include but not be limited to start, door control, motoring, coasting, braking and emergency brake commands. Door control circuit design shall allow opening of doors in stand by position of mode selector under manual responsibility in case of non-availability of door opening authorization from ATP without losing the ATP mode.

TD3.4.3 For train control circuits, Signalling and Telecommunication contractors shall respectively identify the voltage free contacts to be provided by RS Contractor, including the number and type of electrical signals required between the ATP/ATO equipment and the equipment provided by RS Contractor. The contractors shall co-ordinate to agree on levels and protocols for each such signal.

TD3.4.4 As a minimum, all electronic equipment to be mounted on rolling stock, including those provided by Signalling and Telecommunication contractors shall comply with IEC 60571: Electronic Equipment used on Rail Vehicles, for design, manufacture and testing, and shall use components purchased against an internationally recognised quality assurance and reliability certification procedure.

### **TD3.5 Antennae**

TD3.5.1 Signaling and Telecommunication contractors shall identify roof-, bogie-, and underframe-mounted antennae, and associated disconnection box mounting brackets and location requirements to identify cable and conduit routes required to antennae, as applicable.

TD3.5.2 Signalling and Telecommunication contractors, for their respective scope, shall supply the necessary disconnection boxes, terminal blocks, cables and adaptation mounting brackets, flexible conduit assemblies complete with connectors and cables from antennae to the junction boxes.

TD3.5.3 RS Contractor shall provide the antenna mounting brackets, conduits, support or clamping arrangements to ensure security and reliability.

TD3.5.4 The antenna system shall not contravene the kinematic envelope and fully meet the radio coverage requirements both for normal and reverse directions of train working.

### **TD3.6 Speed Measurement Devices**

TD3.6.1 For each ATC equipment set (per driving cab), Signalling contractor shall supply to the RS Contractor for installation, axle mounting speed measurement devices and couplings, to be configured, and the data from them processed in such a way as to achieve the objectives of TD3.6.2 below in fail safe manner. The speed measurement devices shall be mounted on the axles which shall be non-powered and brake free axles.

TD3.6.2 Signalling contractor shall ensure that the speed measurement devices produce a signal which reflects the true speed of the train (within  $\pm 1.0$  kmph) under any operational, weather and track conditions including gradient, curvature, wheel spin/slide. The error in the speed measurement due to wear in wheel diameter, up to laid down limits shall be mitigated by automatic means or other safe methods.

TD3.6.3 Signalling contractor shall supply the necessary disconnection and terminal blocks, device



mounting brackets and plates, flexible conduit assemblies complete with connectors and cables from speed measurement devices to the junction boxes. The signaling contractor will supply all the mechanical fixing items like odometer, Antenna, Pick up coil and cables required for ATC like cables for odometer, Antenna, Pick up coil etc.

TD3.6.4 RS Contractor shall provide for each speed measurement device mounting brackets, support or clamping arrangements to ensure security and reliability.

TD3.6.5 Signalling contractor shall furnish the zero velocity detection apparatus (ZVR relay).

TD3.6.6 Signalling contractor shall furnish RS Contractor with full mounting details, apertures, fixing holes, etc.

### TD3.7 Train operator's Display

TD3.7.1 The equipment on driver's console used for UTO/ATO/ATP/RM/ROS modes shall be ergonomically placed.

Indications to the train operator shall be displayed on the ATC Cab Display supplied by Signalling contractor. The train operator's display will be composed of an integrated display screen. It shall incorporate as a minimum, but need not be limited to the following information:

- (i) Train description, (ID) including crew identification
- (ii) Target Distance
- (iii) Target Speed
- (iv) Service and Emergency Brake Initiation
- (v) Train docked
- (vi) Train hold status
- (vii) Station dwell time available
- (viii) Departure order
- (ix) In ATP zone or not
- (x) ATP/ATO/UTO failure indications
- (xi) Skip Stop indication
- (xii) Door Open Indication
- (xiii) Maximum Permissible Safe Speed (MSS) in ATP, UTO and ATO Modes
- (xiv) Train stopped outside of expected stopping window
- (xv) Depot indication, when the train is identified as being in a depot
- (xvi) Axle locked indication, for axles on which ATC speed sensors are mounted
- (xvii) Door release available; indicating on which side(s) of the train the doors may be opened.
- (xviii) Operating Mode

During design stage, RS and Signalling contractors may have to interface to integrate TCMS/DMI inputs, if considered necessary to optimise the driving console in the cab for operation under GoA3/GoA4 keeping in mind that there will be 2 stages of commissioning. Also, Signalling Contractor shall interface with RS Contractor, to provide required inputs, like current speed, target speed, advisory speed, Normal Stopping Point (NSP) distance and mode of the train, as a minimum, to RS HMI for display purposes.

### TD3.8 Interface between TCMS and on-board signalling Equipment and OCC

TD3.8.1 The Rolling Stock Contractor shall provide an on-board Train Control Management System (TCMS), to log the information from the ATP/ATO/UTO and Train Radio equipment supplied by Signalling and Telecommunication contractors respectively, in addition to the information shown in the Rolling Stock specification.

- TD3.8.2 Data stored in the TCMS shall be password protected. Levels and protocols shall be agreed between the Contractors. Software for downloading the data from TCMS to maintenance terminal shall be provided by RS Contractor. Signalling and Telecommunication contractors, as applicable, shall provide Windows compatible software for maintenance terminals for viewing the data logged in TCMS. It shall be possible to extract the data remotely from TCMS to a suitable terminal at OCC.
- TD3.8.3 All the commands by the on-board ATP, UTO and ATO systems to Rolling Stock equipment and the responses of the rolling stock equipment to these commands, shall also be recorded in TCMS.
- TD3.8.4 The signals to be supplied from the TCMS to the equipment of Signalling and Telecommunication contractors shall be decided jointly between the Contractors.
- TD3.8.5 TCMS shall be able to communicate data to OCC/SCR/DCC on the Rolling Stock terminal of ATS system. The data shall contain identified train alarms. Signalling and Telecommunication contractors shall interface to make the data available to its destination in OCC/SCR/DCC.
- TD3.8.6 The interface shall ensure that TCMS receives necessary inputs from the on-board ATP system to enable TCMS to synchronize its clock with the system master clock. All the microprocessor/ micro-controller based on-train systems shall synchronize respective clocks with TCMS clock.
- TD3.8.7 Deleted.

### TD3.9 Power Supply and Earthing Arrangements

- TD3.9.1 Independent 110V DC power supply circuits, including positive and negative poles, at least three for ATC and one for Train Radio Equipment shall be provided by RS Contractor and there shall be no physical or electrical links between these power supply circuits.
- TD3.9.2 RS Contractor shall provide dedicated earthing arrangements for the train borne ATC and radio equipment. Signalling and Telecommunication contractors shall specify the earth impedance required.
- TD3.9.3 The power supply cable between the train power supply and the ATC and radio train borne equipment shall be segregated, as short as possible and directly connected to the supply without any intermediate connection.

### TD3.10 Telecommunications

- TD3.10.1 Telecommunication contractor shall furnish RS Contractor with the interface required between the train radio system and the on-train public address system to allow on-board announcements to be made from the OCC. The interface shall provide the necessary means to enable OCC to initiate triggering of pre-recorded messages in the on-train public address system.
- TD3.10.2 The complete on-train public address system, and interface hardware, including the transmission link, and a communication panel shall be furnished by RS Contractor. Levels and protocols shall be agreed between the two contractors.
- TD3.10.3 RS Contractor shall provide Train ID to train radio through TCMS-Train Radio interface.
- TD3.10.4 Telecommunication contractor shall furnish RS Contractor with the interface required between the train radio system and the TCMS for recording the initiation, termination, and success or failure of emergency calls initiated by the train operator and/or OCC on the radio. The hardware interface shall be furnished and installed by RS Contractor. Levels and protocols shall be agreed between the two contractors.
- TD 3.10.4.1 There shall be a provision of roving attendant to make the passenger announcement through his/her mobile handset (Tetra) inside a particular train through train radio network using radio identification number. The interface between train radio and on board communication (PA/PIS) system shall be done by rolling stock and telecommunication contractor.
- TD3.10.5 Telecommunication contractor and Rolling stock contractor shall interface for initiation, termination and success or failure of emergency calls initiated by passengers to OCC. The initiation of this passenger call shall automatically focus a CCTV camera on the passenger



and raise a prompt on a suitable terminal of OCC/BCC. The hardware interface shall be furnished and installed by RS Contractor.

### TD3.11 Factory Installation and Testing

- TD3.11.1 All the special equipment associated with the train borne ATC and radio system, including the interface cables / wires between the train borne ATC and Train Radio shall be designed and supplied by Signalling and Telecommunication contractors, as applicable, to RS Contractor's factory. Each contractor shall be aware of the locations of manufacturing plants, which could concurrently be manufacturing cars.
- TD3.11.2 Signalling and Telecommunication contractors shall be responsible for providing all data and training of RS Contractor's staff in all aspects of ATC and train radio installation and testing wherever applicable. The first set of ATC equipment and also Train Radio equipment shall be installed by RS Contractor, under the supervision of Signalling and Telecommunication contractors' representatives, including the wiring for the interface of the ATC equipment with Rolling Stock.
- TD3.11.3 RS Contractor shall be responsible for installing wiring and equipment and its testing on each car to the functioning standard agreed with Signalling and Telecommunication contractors.
- TD3.11.4 Testing of each car shall comply with the accepted international standards agreed between the contractors as agreed with the Engineer. Initial integration tests (static) shall be done at the rolling stock factory and carried out by the test personnel of respective contractors jointly. Further main line integration tests (static and dynamic) will be required to be carried out to ensure all train control functions and telecommunications between OCC and Train which will be required to be done jointly by RS, Signalling and Telecommunication contractors at site in Mumbai. The test certificate subsequently shall be issued jointly by RS, Signalling and Telecommunication contractors. The certificates will pertain to the respective areas of the contractor's responsibility and shall be decided during the interface.
- TD3.11.5 RS Contractor shall provide facilities for comprehensive static and interface tests between the Rolling Stock, Signalling and Telecommunications systems at his premises. Signalling and Telecommunication contractors shall be responsible for the provision of special test equipment and instrumentation.
- TD3.11.6 In case of UTO & ATO, the Integration test between RS and Signalling contractors shall include tests on mainline to confirm the realisation of demanded acceleration and deceleration rate by the UTO/ATO under various conditions.
- TD3.11.7 Should the need arise for modifications in the configurations of respective equipment or systems as a result of Integration Test or otherwise, the scope of work and division of responsibility shall be jointly agreed amongst the contractors and detailed procedure shall be developed. RS Contractor shall provide the requisite manpower to monitor and/or implement the modifications on the rolling stock for work involving scope as identified in clause TD3.11.3 above.
- TD3.11.8 The rolling stock contractor and signaling contractor(s) shall fully associate and render all necessary support during type testing of the respective systems. Rolling stock type tests may require "All-Out" mode of operation in GoA4 as per approved test specifications, the rolling stock contractor & signaling contractor(s) will jointly finalize such test plan and schemes/operational modes and ensure the satisfactory completion of type tests.

### TD3.12 EMC/EMI Interface

- TD3.12.1 Regarding electromagnetic interference, Signalling contractors shall provide a list of frequencies and other sensitive requirements to the RS Contractor, to enable RS Contractor to avoid such frequency bands in design, and to provide devices to isolate the source of emission wherever required. The Signaling Contractor will have first right of use for radio frequency 2.4GHz/5.8 GHz for CBTC application.
- TD3.12.2 RS, Signalling and Telecommunication Contractors shall ensure that the emission and immunity level of their respective equipment meet the requirements of EN50121-3-1 & EN50121-3-2.
- TD3.12.3 RS Contractor shall ensure that the return current in the track at the specified frequencies does not exceed the value specified by Signalling Contractor.

- TD3.12.4 The Contractors shall also jointly develop a test plan for verification of electromagnetic compatibility of traction and signalling and also telecommunications systems. The contractors shall work together to assure that all electronic and electrical equipment on the rolling stock works properly without interfering with signalling, or telecommunications sub-systems.
- TD3.12.5 The cable layout of the signalling and communication system in the cable ducts provided by RS Contractor shall be jointly agreed. The separation between signalling and communications cables and power cables of 25kV, 415 V three phase AC, 230 V AC single phase, 110 V DC rating shall be in accordance with accepted international practice and jointly agreed.
- TD3.12.6 The cable ducts shall be earthed at notionally at every 2 m and also at the ends and shall be in accordance with accepted international practices.

#### TD4. INTERFACE- Division of Responsibility

- TD4.1.1 RS Contractor shall coordinate with Signalling and Telecommunication Contractors in order to achieve the functional and operational requirements of the system. The roles and activities of the Contractors shall broadly include minimum but not limited to those mentioned in table TD.1 below.

Table TD.1 Division of Responsibility

Item	Signalling	Telecommunication	Rolling Stock
1. On board VATC equipment 2. Deleted 3. Antennae for ATP, ATS and TWC 4. Speed measuring sensors and speedometer for non-ATC mode. 5. ATC Cab Displays (Train operators MMI). including special cables etc.	To supply the equipment to the Rolling Stock Contractor's Works		To provide space in the vehicle design for fixing and installation at the manufacturer's facility, by the Rolling Stock Contractor, under the supervision of the Signalling and Train Control Contractor. The speed measuring sensor and odometer for non-ATC mode will be provided by Rolling Stock Contractor.
6. On board radio equipment 7. Antennae for CBTC, CCTV & train radio including special cables etc. 8. Train lines/Ethernet connection	To supply the equipment to the Rolling Stock Contractor's Works.  Furnish the requirement	To supply the equipment to the Rolling Stock Contractor's Works	To provide space in the vehicle design for fixing and installation at the manufacturer's facility, by the Rolling Stock Contractor, under the supervision of the Signalling and Train Control and Telecommunication Contractor. To provide train lines/Ethernet Connection as per signalling requirement.
9. Power supply and earthing for on board ATP/ATO/UTO and train radio equipment.	Furnish required voltage values and earthing requirements to Rolling Stock Contractor for respective scope.		To provide the required voltages and earthing



10. Logging of on-board information from ATP/ATO/UTO	Signalling and Train Control Contractor to co-ordinate with Rolling Stock Contractor for signal levels and protocols.		Provide the on board data logger TCMS. All to and fro signals shall be logged in TCMS.
11. Interface between ATP/ATO/UTO with train braking and propulsion systems for automatic braking, acceleration and deceleration.	ZVR & redundant EBR relays to be supplied by the Signalling and Train Control Contractor		Rolling Stock Contractor shall co-ordinate with the Signalling and Train Control Contractor to agree on levels and protocols for interface signals. There shall be no delay in braking from RS during the transition from ED to friction brake at slow speed.
12 System master clock	Signalling and Train Control Contractor to provide necessary inputs.		Rolling Stock Contractor to synchronize TCMS clock with the system master clock. All sub-systems clock in RS shall be synchronised with the TCMS clock.
13. On board next station information to the passengers	Shall provide necessary signals on-board to Rolling Stock Contractor.		Shall provide for necessary hardware interface, display for on-board P.A. system inside the cars.
14. On board announcement from OCC including triggering of pre-recorded messages.		Shall provide necessary signals on-board to Rolling Stock Contractor	
15 Climatic requirements for on board ATP/ATO/UTO and radio cab equipment.	Signalling and Train Control Contractor to specify at an early date, the total heat load wattage, and maximum permitted temperature		Rolling Stock Contractor to provide Cab Air Conditioning installation to maintain a nominal temperature of 25°C. Suitable ventilation shall be provided by the contractor for the backside area of the console. Rolling Stock Contractor to provide conditioning air from the saloon to all relevant signal & telecom installations to maintain a nominal temperature of 25°C. Conditioned air ventilation shall be provided by the Contractor for the console.
16 Climatic requirements for on board Train Radio cab equipment.		Telecommunication s Contractor to specify at an early date, the total heat load wattage, and maximum permitted temperature	
17. EMI/EMC interface between the Rolling Stock and Signalling and Train Control, and Telecommunications.	Signalling and Train Control, and Telecommunications Contractors shall advise EMI/EMC plan for ATP/ATO & radio equipment to Rolling Stock Contractor at early date.		Rolling Stock Contractor shall ensure the compliance of the requirements of Signalling and Train Control, and Telecommunications Contractors for on board ATP/ATO and radio equipment.

18. Train Integrity Information		Train integrity information will be provided by Rolling Stock to ATC onboard.
19. Data transmission methodology for control command	Signalling Contractor to interface with Rolling Stock Contractor for selection of best suited methodology i.e. bit by bit, code(1 byte) or any other.	Rolling Stock Contractor to provide details for VATC to TCMS communication.
20. The polling cycle and delay times assessment between OCC and onboard VATC/CCTV	The Signalling Contractor shall assess and furnish to Rolling Stock Contractor the polling cycle time, data transmission time(rate) between OCC and onboard VATC/CCTV under best and worst case scenarios for both CBTC and CCTV networks.	The Rolling Stock Contractor to provide TCMS to VATC/CCTV interface requirements to Signalling Contractor to comply with functionality as specified in the Rolling Stock contract.
21. Deleted		
22. Standalone door operation	Signaling to give standalone door operation command to allow driver/cleaning staff to enter/exit the train from designated door in designated Depot area/Main line siding.	Rolling Stock Contractor shall give the necessary support to the Signalling contractor.
23. Ground based hot axle box detection for monitoring of axle box temperature	The Telecom Contractor shall provide Ethernet channel from station TER (Telecom Equipment Room) to CER (Central Equipment Room) of OCC.	The ground equipment shall be provided by RS Contractor or third party.  The server/work station/terminal with suitable application software and interface equipment if any in OCC shall be provided by Rolling Stock Contractor.
24. Graphical User Interface (GUI) for RS controller	Signalling contractor shall be responsible for providing necessary support during interface finalization to the RS contractor	Rolling Stock Contractor shall be responsible for development of the GUI (including hardware) for the RS controller (RSC) in the OCC. Any other GUI(s) in OCC/BCC shall not be the scope of RS contractor.



25. Guaranteed Emergency Brake Rate(GEBR)		Rolling Stock Contractor shall furnish value of GEBR to Signalling Contractor.
26. Emergency Brake application validation at low speed ( $\leq 25$ kmph) as a part of wake up procedure	Signalling Contractor shall validate the EB Test based on details furnished by RS Contractor.	RS Contractor shall furnish the pass/fail criteria based on the speed achieved and gradient of the track to the Signalling Contractor.
27. Live streaming from TCMS to OCC/BCC and Live transmission of advertisements from OCC/BCC to train via CCTV network.	Signalling Contractor shall provide suitable buffering arrangement for live video streaming transmitted from the train to the OCC/BCC via CCTV network and for its onward multicast transmission to other terminals/networks.	RS Contractor shall provide - <ul style="list-style-type: none"> <li>• Suitable Buffering arrangement on the train for live video streaming.</li> <li>• Live video players with buffering capability.</li> <li>• Advertisement and Live video players in hot standby per train.</li> <li>• Redundant suitable arrangement (video controller/player/servers) in OCC/BCC for transmission of live video contents and stored video contents to be played in the train.</li> </ul>
28. Signals for neutral section	Will protect the entry of train in neutral section in ATP/ATO mode. Also, will provide necessary signal to TCMS for Panto management around Neutral Section.	In case, signal for Panto management fails, the RS Contractor will ensure that the information about neutral section is available on TCMS.

<p>29.Platform Screen Doors</p>	<p>Signalling and PSD Contractor shall exchange the defective/isolated train door and PSD door information with RS Contractor.</p>	<ul style="list-style-type: none"> <li>• Rolling Stock contractor shall provide KE and door drawings of train to PSD contractor for placement of Platform Screen Doors.</li> <li>• Shall share location of ERD/EAD and parking brake release lever along with their operating mechanism with Signalling Contractor.</li> <li>• Shall interface with PSD Contractor for synchronization of train door/PSD opening and closing.</li> <li>• Shall exchange the defective/isolated train door information with Signalling and PSD Contractor.</li> <li>• Shall interface with Signalling and PSD Contractors for provision of reclosing the door(s) without opening all doors in case of obstruction detection.</li> </ul>
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**Annexure 1/TD: Rolling Stock Characteristics**

Table TDA1.1 : Rolling Stock Characteristics

Train composition	DM-T-M-M-T-DM
Minimum Design Average Acceleration rate for fully loaded (AW3) train on level tangent track shall be as under: 0 kmph to 40 kmph 0 to 60Kmph 0 to 80Kmph	1.0 m/s <sup>2</sup> 0.75 m/s <sup>2</sup> 0.40 m/s <sup>2</sup>
Minimum Operational Average Acceleration rate for AW2 loaded train on level tangent track shall be as under: 0 kmph to 35 kmph 0 to 60Kmph 0 to 80Kmph	1.20 m/s <sup>2</sup> 0.80 m/s <sup>2</sup> 0.45 m/s <sup>2</sup>
Average Service braking rate from 80kmph to standstill for fully loaded (AW3) train on level tangent track	1.0 m/s <sup>2</sup>
Average Service braking rate from 80kmph to standstill for AW2 train on level tangent track	1.1 m/s <sup>2</sup>
Average Emergency braking rate from 80kmph to 0 kmph for fully loaded train on level tangent track	1.3 m/s <sup>2</sup>
Jerk rate (Maximum)#	0.75 m/s <sup>3</sup>
The Emergency braking distance of 6- car train set with all bogie working under fully loaded condition	245m
*Service Brake Response Time	2.0s
*Emergency Brake Response Time	1.5s max
*Service and Emergency Brake Release Time	2.5s
Resistance to motion (formula, curve, starting resistance)	TR = 21.96 + 0.4222V + 0.00876V <sup>2</sup> N/t for Underground Section. TR = 14.01 + 0.264V + 0.00191V <sup>2</sup> N/t for Elevated/At grade Section. (V in kmph)
Maximum wheel diameter	860mm
Minimum wheel diameter	780mm
Safe train speed	90 kmph
Door opening and closing times	Open 2.5 s (Max.) Close 3.5 s (Max.)
Tare weight of a unit	126T for 3-car unit with weight of any car not exceeding 42T.
No of axles per Car	4
Presence of non service brake and non powered axles	All DM & M axles are powered while axles of T cars are non-powered.  All axles are equipped with friction brake mechanism.
Maximum Axle Load	17 tonne
Train length – 6 Car Train	136m approximately
Maximum Length over couplers for all cars	23000 mm
Maximum Length over Body(including end-fairings)	22,010mm
Maximum Width over Body	3,200 mm
Maximum Vehicle Overhang	3630 ± 175 mm

Note :

- All of the data in the above table are notional, and should be confirmed between the Contractors. The above data is not exhaustive, and full co-operation between Contractors is required.
- For the items marked \*, the maximum timings are for a brake application from initiation of brake application command from BECU to 90% of full Brake Cylinder Pressure (BCP) and for brake

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release from initiation of brake release command from BECU to 10% of BCP.

3. For the item marked #, the Rolling Stock Contractor as well as Signalling Contractor shall comply EN 13452-1 or equivalent international standards for jerk determination and methodology shall be finalized during design stage with the approval of Engineer.



**APPENDIX TE. DRAWINGS AND DOCUMENTS****TE1 General**

TE1.1 The list of drawings and documents is furnished in table TE.1.

Table TE.1 List of Drawings

S. No.	Description	Drawing / Document reference
1*	Kinematic Envelopes(6 no. drawings)	Attached in Part-II :Section 6D
2	General Alignment drawings:	
(i)	General Alignment drawings Dahisar East to Mandala	Attached in Part-II (In Compact Disk)
(ii)	General Alignment drawings Dahisar East to Andheri East	Attached in Part-II (In Compact Disk)
3	Proccedure for Safety Certification and Technical Clearance of Metro Systems	Attached in Part-II :Section 6E
4	Guidelines for Noise and Vibrations for Metro Rail Transit Systems	Attached in Part-II :Section 6F
5	The Metro Railways General Rules	Attached in Part-II :Section 6G

TE1.2 Documents and drawings marked \* are enclosed within the Employer's Requirements: Technical Specification.

TE1.3 In case speed restrictions are not mentioned in the General Alignment Drawings, Bidders may refer Appendix-1 of SOD: Permissible Speed, Cant and Minimum Track Spacing on Curves.

**APPENDIX TF. SUBMITTALS****TF1 General**

TF1.1 As per various clauses of this Employer's Requirements: Technical Specification, the Tenderers/Contractors are expected to submit relevant information. A list of the required documents / information is given in below mentioned tables along with the respective clause reference.

**Table TF.1.1 Submittals by Tenderer**

S. No.	Description	ERTS Clause Reference
<b>Chapter 2</b>		
1.	Expected MDBCF of Major Systems	2.8.2 (xi)
2.	Specific exceptions for LRU's, whose replacement is not achievable in 30 minutes	2.12.9
3.	Expected MTTR for Major Systems as listed in Table 2.3 of ERTS.	2.12.10
<b>Chapter 3</b>		
1.	Designs along with Technical Data based on specification, sound proven and reliable engineering practices	3.2.1
2.	Confirmation of provenness of equipment / sub-system / system and exceptions thereof	3.2.2
3.	Confirmation of provenness of propulsion equipment	3.2.3
4.	Confirmation of Kinematic Envelope	3.20.3
5.	Cars Conform to the Latest version of SOD	3.20.6
6.	Train Resistance and guaranteed performance	3.21.5
7.	Performance Characteristics	3.22
<b>Chapter 4</b>		
1.	Details on technique of joining modular elements of shell	4.1.1
2.	Details of Manufacturing process	4.4.5
3.	Proposal on structural arrangement	4.8.5
4.	Predicted values towards cash worthiness of cars	4.8.6
5.	Means of uncoupling a semi-permanent coupler	4.15.1
<b>Chapter 5</b>		
1.	Details on provenness of bogie along with performance certificates from end user	5.1.1
2.	Detailed comprehensive proposal on the Brake system along with the proof of provenness.	5.12.1
<b>Chapter 6</b>		
1.	Brief description of the proposed brake system along with the expected life of brake pads.	6.13.13
<b>Chapter 7</b>		
1.	Time required to replace, adjust and test a door leaf	7.2.1 (xv)
2.	Proposed design for sealing of the guides	7.2.1 (xii)
3.	Details of locking device for door leaves	7.2.4.3 (i)
<b>Chapter 8</b>		
1.	Mounting details of transformer	8.7.5
<b>Chapter 10</b>		
1.	The proposed standards on Data protocols	10.1.9
<b>Chapter 11</b>		
1.	Specific measures taken to minimise energy consumption for HVAC	11.1.7
<b>Chapter 14</b>		
1.	Details on latest internationally accepted practice for Soldering of electronic components	14.15.3



Table TF.1.2 Submittals by Contractor

S. No.	Description	ERTS Clause Reference
<b>Chapter 2</b>		
1.	CV of Interface Manager	2.2.8
2.	Quality Assurance Plan	2.3.1
3.	Safety Assurance Plan	2.4.1
4.	Hazard Analysis	2.5.3
5.	Fire Safety Design Report	2.5.8
6.	Reliability, Availability and Maintainability Plan	2.7.3
7.	Reliability Model	2.7.6
8.	Reliability Apportionment and Prediction Report	2.7.8
9.	Pattern Failure Targets	2.8.1 (iv)
10.	EMC Control Plan	2.15.1
11.	Noise and Vibration Assurance plan	2.18.2 (i)
<b>Chapter 3</b>		
1.	List items for Engineer's approval of vendors	3.2.5
2.	IMP and detailed interface documents	3.6.1
3.	Copies of the applicable standards along with design documents	3.7.1
4.	Design Review Schedule	3.8.2
5.	Static vehicle profile of the proposed cars to suit the Kinematic Envelope	3.20.2
6.	Detailed calculations showing lateral and vertical shifts due to each factor indicated in clause 3.20.1	3.20.3
7.	Detailed calculation for minimum clearance between the carbody exterior and platform edge as per clause 3.20.5	3.20.5
8.	Declared value of Specific Energy Consumption (SEC)	3.24
<b>Chapter 4</b>		
1.	Calculations of Carbody's Camber	4.6.4
2.	Fatigue life assessment of Carbody structure	4.6.6
3.	Proposal for Roof and Roof-mounted equipment	4.16.1
4.	Calculations related to Obstacle Detection Device	4.18.2
<b>Chapter 5</b>		
1.	Calculations supporting selection of axles & bearings	5.1.3
2.	Calculation of Derailment Quotient (Y/Q)	5.2.5
3.	Proposal for vehicle dynamic analysis & it's model	5.2.7
4.	Calculations for Bogie Frame strength	5.3.2
5.	Corrosion Protection Plan for Bogie Frame	5.3.6
6.	Proposal for primary suspension system of proven helical coil steel springs	5.4.1
7.	Calculations of proposed secondary suspension	5.4.2
8.	Safety Factor used for Bogie-Body connection	5.5.2
9.	Detailed Calculation of Natural Frequency of motor suspension system	5.9.3
10.	Test procedure for gearbox	5.10.4
11.	Ultrasonic Testing for powered and non-powered axles	5.15.5
<b>Chapter 6</b>		
1.	Calculations of Compressor's capacity to meet worst condition	6.2.2
2.	Letters from actual users indicating experience with compressors on their system	6.2.4
3.	Technical details of proposed Air Dryer	6.4.4
4.	Calculations for reservoir's size	6.5.1



5.	Detailed plan for pneumatic circuit isolation arrangement	6.7.11
6.	Brake Calculations & EBD under dry & wet conditions.	6.13.14
7.	Certificates for SIL levels of Brake System	6.13.20
8.	Proposal for Brake blending logic	6.14.2
9.	Brake effort vs. Speed Characteristics	6.14.5
10.	Guaranteed maximum Braking distance and guaranteed deceleration rate	6.16.9 & 6.16.10
11.	Brake control interface with VCC	6.17.2
12.	Brake operating Timing Diagram	6.19.1
13.	Details for WSP scheme & equipment	6.22.2
14.	Exhaustive documentation & animations on complete pneumatic system	6.24
<b>Chapter 7</b>		
1.	Door control system test procedure	7.2.1(v)
2.	Details of microprocessor based DCU	7.2.1(xvi)
3.	Documentation for flow charts, Signal flows and interpretation of signal etc.	7.2.1(xvii)
4.	Relevant SIL Certificates for Door system	7.2.1(xxii)
5.	Comprehensive proposal for door mechanisms	7.2.2(iv)
6.	Door control push button details and schematic	7.2.4.4 (ii)
7.	All details of other metros for proposed design of Front end emergency door	7.3.2
8.	Detailed proposals of operation of detrainment doors	7.3.7(iv)
9.	Detailed evacuation plan	7.3.9
<b>Chapter 8</b>		
1.	Complete roof layout along with clearance between roof equipment	8.1.6
2.	Expected frequency for replacement of Panto strip in terms of kilometers earned by car	8.2.7
3.	Supporting calculations for width & profile of pantograph and wind tunnel test results	8.2.8
4.	Declaration of vendors for transformer sub-assemblies and undertaking and commitment from vendors for direct procurement in future	8.7.9
5.	Test report & design life of gasket & sealant	8.7.14
6.	Details for roof end and transformer end terminations	8.8.1
7.	Design calculations for power converter-inverter	8.9.7
8.	Quality specifications of regenerated energy including harmonic analysis, detailed documentation on interlacing strategy and harmonic reduction measures	8.9.11
9.	Detailed report on minimum substation capacity based on operational requirements	8.9.18
10.	Detailed document for by pass ground switch used in CI box	8.9.20
11.	Detailed document for 24VDC LED based lighting arrangement in CI box	8.9.21
12.	Calculation for choice of bearings of Traction Motor	8.10.7
13.	Power Ramping Characteristics for Neutral Section Detector	8.11.2
<b>Chapter 9</b>		
1.	Detailed document for additional by pass ground switch in SIV Box	9.2.13
2.	Detailed document for 24V DC LED based lighting arrangement for SIV box	9.2.15
3.	Design calculation for sizing of Battery	9.4.5
4.	FEM and fatigue report of battery box	9.5.5
<b>Chapter 10</b>		
1.	Comprehensive list of capabilities of TCMS	10.1.1



2.	Basic architecture & hardware of TCMS	10.1.2
3.	Details of all UTO specific design functionalities	10.1.6
4.	TCMS configuration details	10.1.8
5.	Switchover and recovery times of redundant processors	10.2.5
6.	Failure redundancy matrix for TCMS	10.2.6
7.	Detailed proposal for spare capacity of TCMS components	10.2.7
8.	Proposal for labelling of TCMS interconnections, cabling & terminals.	10.2.11
9.	Verification report to ensure maximum CPU loading	10.2.12
10.	Details of network integrated systems	10.3.1
11.	Details of communication protocols	10.3.3
12.	Detailed clock synchronisation protocol	10.3.5
13.	Technical details of TCMS control system	10.4.3
14.	List of functions /features proposed to be controlled through TCMS	10.4.5
15.	Detailed scheme for protective controls	10.4.6
16.	Details of TCMS self –diagnostic tests	10.6.1
17.	Proposed scheme for fault diagnostic	10.7.1
18.	Details of failure management actions	10.7.3
19.	Detailed proposal for auto-upgradation of frequent faults	10.7.6
20.	Graphics and animation for operator mode of TSD	10.8.3
21.	Naming convention for all different data file types	10.10.7
22.	Detailed arrangement at test points for measurement of energy consumption	10.12.3
23.	Detailed information of the TCMS-OCC interface as implemented in at least two recently executed UTO projects.	10.13.3
<b>Chapter 11</b>		
1.	Measures to prevent unloading of HVAC units under train stoppage conditions due to high condenser temperature.	11.1.3
2.	Estimated weight, power requirements & heat load calculations for the parameters of HVAC	11.1.7
3.	Calculations for inside conditions with one HVAC unit out of operation	11.2.5
4.	Proposal for HVAC air discharge velocities	11.2.6(i)
5.	Proposal for temperature distribution	11.2.6(ii)
6.	EER for offered system for HVAC, record of proven system in any metro with specified COP, expected power consumption of HVAC per car for peak summer, monsoon and winter for AW0, AW1, AW2 and AW3 passenger loads	11.2.14
7.	Declaration of weight of complete roof mounted unit	11.4.3
8.	Proposal for earth fault protection of HVAC	11.13
<b>Chapter 12</b>		
1.	List of control equipment and manufacturers	12.4.1
2.	Specification, voltage grade size and type of cable for different applications	12.5.6
3.	List of indicators including function, control & display	12.6.2
4.	Detailed protections scheme	12.7.1
5.	Earth Fault Detection System	12.7.5
6.	Design of heat dissipation arrangement with simulated results for interior illumination system	12.9(4)
7.	Complete light and energy simulation calculations	12.9(6)
8.	Details of control logic to maximize utilization of the natural light and maintain desired illumination level	12.9.1(vii)
9.	Service life of LED lamp	12.9.1(viii)
10.	Layout of fittings and control circuit	12.9.1(ix)

11.	Details of the system configuration and components for windscreen wiper	12.10.5(iii)
12.	Technical details of horns	12.10.6
<b>Chapter 13</b>		
1.	Full details for announcement in train by roving attendant with the provision of communication with OCC.	13.2.4
2.	Details of speaker/mic panel provided for PEA	13.3.9
3.	Full details of integrated main communication panel	13.4.1
4.	Details of microphone	13.4.3
5.	Full details of power amplifiers required for PA system	13.4.6
6.	Full details of saloon loudspeakers along with simulation	13.4.7
7.	Full details of software/hardware configurator	13.4.8
8.	Full details of outside speaker	13.4.11
9.	Fire and smoke compliance for complete PA/PIS and PSSS	13.4.13
10.	Procedure and full details for cab to cab communication	13.5.4
11.	Full details for AVAS	13.6
12.	Details of available size of display for PIS	13.7.1(i)
13.	Proposal for destination indicator	13.7.1(iii)
14.	Details of size, location of destination indicator, external side indicator and train no. indicator	13.7.1 (ix)
15.	Details of programmable split screens of PIS and DRM display	13.7.2
16.	Full details for planned and unplanned skip station functionality	13.8.1(iv)
17.	Full details for Wi-Fi internet facility in train	13.11.4
<b>Chapter 14</b>		
1.	Details of all preparatory and post welding procedures for spot welding	14.3.4
2.	Fault discriminating characteristics	14.10.3
3.	Earthing scheme	14.10.7
4.	Apparatus coding and cable & wire designations	14.11.2
5.	Voltage and/or waveform expected at each critical test point of PCBs	14.12.6(i)
6.	Instructions for carrying out testing and troubleshooting and the function of each circuit block of PCBs	14.12.6(ii)
7.	Component layouts of PCBs and assemblies	14.12.6(iii)
8.	Connection or interfacing diagrams for the PCBs and assemblies	14.12.6(iv)
9.	Software quality plan	14.14.3
10.	PCB and connectors: Detailed maintenance and troubleshooting procedures	14.15.6
11.	Technical particulars of lubricants	14.8.1
<b>Chapter 15</b>		
1.	Set of inspection hold points in inspection, testing and commissioning plan	15.3.1
2.	Detailed test procedures for each of the equipment, subsystems, system	15.4.1
3.	Test reports for each identified test	15.4.5
4.	Test and test procedures for integrated testing and commissioning	15.6.2
5.	Service trial procedure	15.7.3
6.	Statement confirming safety and readiness of Rolling Stock	15.7.8
7.	Proposal for combination of test of individual items with system test	15.16.1
8.	Detailed test procedure of instrumented tests carried out at train level both at tare and loaded conditions	15.16.2
9.	Test procedure for TCMS type test	15.20.1



10.	Test procedure, data & results for Noise & Vibration test	15.25.1
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TF1.2 The Tenderers shall include the above information / documents in their bid, as a minimum. Notwithstanding the above, the Tenderers/Contractors shall submit all the required documents / information as specified in various clauses even if the same do not figure in above mentioned table.



**Appendix-TG Train Withdrawal Scenarios for 6-car Trains**

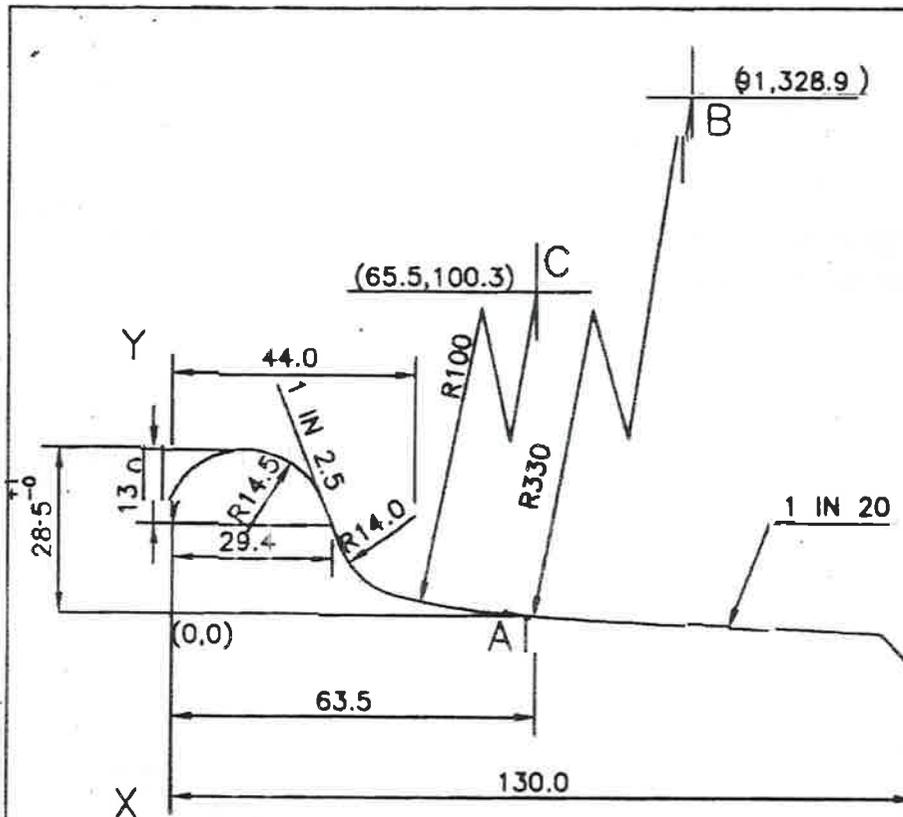
S. No.	System name	Withdrawal Condition
1	Windscreen Wiper and Washer System	- Rainy weather, defective wiper in any cab.
2	Front window	- Broken/cracked front window in the cab - Breakage due to stone throwing / vandalism shall not be on contractor's account.
3	Couplers (any type)	- Any defect.
4	Suspension	- Any defect in primary / secondary suspension resulting in passenger safety, comfort or performance.
5	Wheel	- If wheel flat is > 40 mm or as finalised in design. - Any abnormal hammering as reported by the TO.
6	Pantograph	- Isolation of any pantograph
7	Transformer	- Isolation of any one main transformer.
8	Battery charger	- Battery Charger of one unit isolated.
9	Mechanical drive system	- Any defect resulting in high temperature / isolation - Abnormal Noise from underframe.
10	Traction Motors	- Isolation of more than 4 motors.
11	Traction converters	- As per the consequential effect as defined in Item 10 above.
12	Main compressor unit	- Main Compressor Unit of one unit (3-car) isolated.
13	Air leakage	- Any leakage which necessitate continuous running of compressor. - Any leakages which may lead to incorrect brake application. - Any leakages from brake valves, pantograph, circuit breaker.
14	Auxiliary converter-inverter	- Auxiliary Converter-Inverter unit(s) on one unit (3-car) is isolated.
15	Brake system (mechanical)	- If isolation of an additional bogie (mechanical) leads to speed restriction.
16	Exterior lights	- Failure of any head light / marker light.
17	Driver's desk	- If master controller prevents the train from moving. - Any defect in master controller even if no delays are reported. - Any defective cab switch leading to unsafe operation.



18	TCMS & Vehicle circuits	<ul style="list-style-type: none"> <li>- If HMI display fails &amp; functionality is not transferred to redundant HMI.</li> <li>- Any failure in TCMS component / equipment /circuit element / software/communication system etc. resulting in loss of intended function.</li> <li>- Further cases will be included based on TCMS redundancy and configuration.</li> </ul>
19	PIS & CCTV	<ul style="list-style-type: none"> <li>- If automatic announcements fail &amp; TO is not able to make manual announcements</li> <li>- If announcements in saloon is not audible</li> <li>- if <math>\geq 1</math> unit rear view CCTV not working</li> <li>- If <math>&gt;1</math> PEA in any car is defective</li> <li>- Any of the front CCTV not functioning during GoA4 operation</li> <li>- One saloon CCTV, including its backup if any, is isolated.</li> </ul>
20	Driver's door/ Partition Door	<ul style="list-style-type: none"> <li>- If door cannot be properly closed / locked</li> <li>- If doors are not operable through normal procedure.</li> </ul>
21	Passenger doors	<ul style="list-style-type: none"> <li>- If <math>\geq 2</math> (two) doors per train side is isolated.</li> </ul>
22	Detrainment door	<ul style="list-style-type: none"> <li>- If door cannot be closed or if the safety circuit prevents moving of the train and even if the train can operate as intended though door is defective.</li> </ul>
23	HVAC (passenger area)	<ul style="list-style-type: none"> <li>- Failure of any one HVAC in any car leading to increase in inside saloon / cab temperature <math>\geq 28^{\circ}\text{C}</math></li> <li>- Failure of two HVAC's in one car.</li> <li>- Noisy Air Conditioner.</li> </ul>
24	Ground fault in DC Circuit	<ul style="list-style-type: none"> <li>- Train to be withdrawn in case of single ground fault if it leads to unsafe operation as per the design.</li> </ul>
25	A failure or symptom which may endanger safe and/or normal operation of train	<ul style="list-style-type: none"> <li>- Failure in safety interlock or protection circuit such as door loop</li> <li>- Abnormal noise in underframe</li> <li>- Wheel flat</li> <li>- Arcing in pantograph</li> <li>- Failure of emergency equipment</li> <li>- Failure which may disable train's push out duty.</li> <li>- Train which that requires more than 2 instances of reset within 30 minutes</li> <li>- Jerky movement.</li> </ul>

**Note:**

In case the Withdrawal Condition arises solely for reasons not attributable to the Contractor, the failure shall not be to Contractor's account and shall not be considered for MDBF calculation.



**PROCEDURE OF DRAWING:—**

1. DRAW A VERTICAL LINE X-Y.
2. DRAW SEMI-CIRCLE OF 14.5R TANGENTIAL TO LINE X-Y.
3. DRAW LINE 1:2.5 TANGENTIAL TO 14.5R SEMI-CIRCLE.
4. DRAW A HORIZONTAL LINE AT 28.5mm FROM THE TOP OF THE FLANGE. AND LOCATE Pt. 'A' AT 63.5mm FROM THE LINE X-Y.
5. FROM Pt. A LOCATE CENTRE 'B' OF ARC OF 330R ON A VERTICAL LINE AT 91mm FROM X-Y.
6. DRAW ARC OF 330R FROM CENTRE 'B'
7. LOCATE CENTRE 'C' ON VERTICAL LINE AT A HORIZONTAL DISTANCE OF 65.5mm FROM THE LINE X-Y SUCH THAT BC= (330-100) ie 230mm.
8. DRAW ARC OF 100R WITH CENTRE AS 'C'.
9. DRAW ARC OF RADIUS 14mm TANGENTIAL TO 100R ARC AND LINE 1:2.5.
10. DRAW LINE 1:20 TANGENTIAL TO 330R ARC.
11. DRAW A VERTICAL LINE AT A DISTANCE OF 130mm FROM THE FLANGE END.

**NOTE:**

CO-ORDINATES OF POINTS B & C ARE BASED ON NOMINAL DIMENSION OF 28.5mm.

SUPERSEDED BY:	
SUPERSEDES:	
SCALE	1:1
I.P.	C
	D
	G.V. RAMAN
	T
	J.S.

**WORN WHEEL PROFILE**

③	SS/24/04	DIMENSION 73.7 DELETED	9/04
②	CO/3/94	REVISED & REDRAWN	3/94
①	CO/7/92	CO-ORDINATES OF ARCS SHOWN	3/92
ALT	AUTH.	DESCRIPTION	DATE

B.G. R.D.S.O. (C) GROUP 2213

**SKETCH-91146**

000594

