GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION
FOR
1676 mm GAUGE 9500 HP 6 AXLE
IGBT BASED 3-PHASE DRIVE
ELECTRIC FREIGHT LOCOMOTIVE

Specification No. RDSO/2006/EL/SPEC/0045, Rev. '0'

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ELECTRICAL DIRECTORATE
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CHAPTER 1

GENERAL DESCRIPTION AND CONTRACTOR'S RESPONSIBILITIES

1.0 Introduction

1.1 Electric Traction is the most important mode of traction on Indian Railways, especially on freight carrying routes and high-density routes. Indian Railways are today having 17450 route kms of its tracks under the electric traction system, which caters to 60% of its freight and 47% of its passenger traffic. Currently the most powerful locomotive employed for freight operation is 6 axle, 6120 Horse Power WAG9 class of GTO based three phase drive electric locomotives, which were inducted in 1996-97 and are currently being produced at Chittaranjan Locomotive Works of Indian Railways.

1.2 Due to rapid growth in freight traffic, Indian Railways have decided to set up a dedicated freight corridor to enable haulage of longer and heavier freight trains at higher average speeds. Therefore need has been felt for induction in Indian Railways of electric locomotive based on latest proven technology having higher power and tractive effort.

1.3 This specification defines the technical requirements of design, development, manufacture, testing, supply, delivery and commissioning of 1676 mm gauge high horse power IGBT based 3-phase drive electric locomotive along with spares, tools, documentation etc. for use in Indian Railways.

1.4 The performance requirements, environmental & service conditions, technical requirements and inspection, tests and trials are specified in the following chapters of this specification.

1.5 The design and manufacture of equipment shall be based on sound, proven and reliable engineering practice. The equipment used in different sub-systems shall be of proven technology and design.

2.0 Abbreviations and Definitions

'IR' means Indian Railways

'RDSO' means Research Designs & Standards Organisation

'CLW' means Chittaranjan Locomotive Works

'Tenderer' means Firm/companies participating in the tender

'Contractor' means the person, firm or Company with whom the order for supply of the work has been placed.

'Sub Contractor' means any person, firm or company from whom the contractor may obtain any materials or fittings to be used for the works

'Purchaser' means the President of the Republic of India as represented by the Railways organisation entering into the contract.

'Inspecting Officer' means person, firm or department nominated to inspect the locomotive or the representative of the inspecting officer so nominated

'TOT' means Transfer of Technology

'OEM' means Original Equipment Manufacturer

'BG' means 1676 mm Broad Gauge used in IR

'IS' means Indian Standard

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'IRS' means Indian Railways Standard

'IEC' means International Electrotechnical Commission

'IEEE' means Institution of Electrical and Electronics Engineers

'UIC' means Union International des Chemins de fer (International Union of Railways)

'ORE' means Office of Research and Experiment if the 'UIC'

'ISO' means International Standards Organisation

3.0 References to Various Standards:

This Specification is based on the following Normative References and standards

1. IEC 61133 : Electric Traction – Rolling Stock – Test methods for electric and thermal /electric rolling stock on completion of construction and before entry into service
1. IEC-61287 : Electronic Power Converter mounted on board rolling stock.
2. IEC-60571 : Specific rules concerning the electronic control part of converters.
3. IEC – 60349 –2 : Electronic converter fed alternating current motors
4. IEC-563-1976 : Permissible limiting temperature in services for component of electrical equipment of traction vehicles.
5. IEC –505-1975 : Guide for the evaluation and identification of insulation systems of electrical equipment.
8. IEC –61375-1 : Electric Railway Equipment-Train Communication Network.
9. IEEE – 429 : IEEE recommended Practice for thermal evaluation of sealed insulation systems for AC electric machinery employing form-wound pre-insulated stator coils for machines rated 6900 V and below.
10. EN 50121-3-2 : Railway applications – Electromagnetic compatibility – Part 3-2 : Rolling stock – Apparatus.
11. EN 50121-2 : Railway applications – Electromagnetic compatibility – Part 2 : Emission of the whole railway system to the outside world.
12. IEC 310 : Transformer and Chokes
13. BS 149-1984 : Transformer Oil
14. IEC 60056 : Vacuum Circuit Breaker
15. IEC: 60494 Pt.I : Rules for Pantograph of electric Rolling Stock
16. IS 3231 : Relays and Contactors
17. IEC 228, IS 10810 : Cables
18. IEC 60099-4, IS 3070 pt III: Lightning Arrestor
19. IEC 61373 : Railway applications – Rolling stock equipment – shock and vibration test
20. IEC 61131 : Programming languages for PLC

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4.0 Submission of offers

4.1 The offer shall be submitted in five copies. The bidder is required to offer clause-by-clause comments to this specification either confirming acceptance of the clause and elaborating in detail where necessary or indicating deviations therefrom. The bidder shall be specific about deviations required by them.

4.2 Tenderer shall enclose with the offer, details of their system design, weight particulars of each major equipment, details of all major items viz. locomotive body, bogies, suspension arrangement, pneumatics & brake system, transformer, traction converter-inverter, auxiliary converter, traction motor, auxiliary machines, basic software specification, control electronics, compressor, communication protocols, display systems, and any other aspect / equipment which is within the scope of supply of the tenderer. The tenderer shall also submit in their offer the simulated values of the maximum interference currents in the power supply.

4.3 Unit exchange spares and maintenance spare for 3 years requirements of normal service of the locomotive shall be listed out in the tender.

5.0 Scope of Supply

The scope of supply shall extend to the following:

5.1 Supply of complete documentation, final design drawings, calculations, manuals etc. and design details to the satisfaction of IR and support material associated with the operation and maintenance of the locomotives supplied against this specification. The full documentation shall include drawings, design calculations and data, Maintenance Manuals, Operation Manuals, Troubleshooting Directory, Training Manuals, Logistics Manuals, QA documentation etc.

5.2 Supply /installation of special tools, jigs & fixtures and instruments special test equipment, special training instrument required for testing, commissioning, maintenance and operation. The scope shall also include specification for the special tools, jigs & fixtures etc.

5.3 Supply of unit exchange spares and maintenance spare for 3 years requirements of normal service of the locomotive shall be offered. The tenderer shall list out the maintenance spares in the tender.

5.4 Software packages along with the suitable hardware / machines & system support for scrutinising the design calculations and ensuring that it meets the performance requirement.

6.0 Contractor's Responsibilities

In addition to the requirements spelt out elsewhere in this specification, the contractor's responsibility shall also include the following particularly:

6.1 The Contractor shall supply all materials, cartage, tackle, plant, spare parts, samples, special tools and appliances which may be necessary for the complete and efficient installation, testing and commissioning of the locomotives, even though such material or work may not be specifically mentioned in this Specification. The Contractor shall also

supply all labour necessary and technical supervision for the installation, testing and commissioning of the locomotives.

6.2 The contractor shall depute a team of engineers for commissioning, testing and field trials of the equipment in service. The Contractor shall arrange the required instrumentation and carry out detailed tests and field trials jointly with RDSO. The contractor shall ensure availability of tools, testing equipment, measuring instruments & spare parts in adequate quantity for test and field trials, to be done as part of commissioning.

6.3 Purchaser shall supply free of charge basic facilities like space, water & electricity to the extent possible.

6.4 The Contractors shall be entirely responsible for the execution of the Contract in accordance with the requirements of this Specification. The Contractor shall comply with the provisions of the General Conditions and the Special Conditions of the Contract in scheduling, executing, and obtaining the Purchaser's approval of this design (please refer to para 8 below).

6.5 The supply against this contract shall be designed in accordance with the specification and the Contractor's Technical Proposal for the satisfactory performance of the stock in service notwithstanding any approval which the Engineers or the Inspecting Officers may have given:

i) to the detailed drawings prepared by the Contractors,
ii) of a sub-contractor for material,
iii) of other parts of the work involved by the contract,
iv) of the tests carried out by the Contractor, Engineer or Inspection Officer.

6.6 The contractors shall comply with the instructions of the Inspecting Officer, if in his opinion further precautions than those adopted by the Contractors are necessary for the proper execution and safe delivery in India of all parts of the work.

6.7 During the prototype tests/trials or services, if any problem is observed or feed-back information is obtained, which warrants a re-check of the design / manufacture / quality of the equipment and components, necessary action will be taken by the contractor to carry out the required investigations and to incorporate the modifications / improvements considered most appropriate to comply with the specification & to ensure better reliability and performance without any extra costs to the purchaser. The contractor shall not proceed with any modifications / improvements unless approved by RDSO. Such modifications / improvements will be carried out in all locomotives and will be evaluated for their validity for a further period of time as may be agreed mutually in each case.

6.8 Modifications mutually agreed to comply with the specification will be incorporated by the Contractor at his own cost in the locomotives in a manner approved by the purchaser. Drawings incorporating the modifications found necessary as a result of test and trial will be submitted to RDSO for approval before carrying out the modifications.

6.9 In the event of the Contractor's failing to carry out any work, for which he is liable under this clause, within a reasonable time of two months, or if in the opinion of the engineers the urgency of the case demands it, the Purchaser may, without prejudice to his other rights under the Contract, carry out the work himself at the expense of the contractor.

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6.10 The Contractor shall further, notwithstanding any exercise by the Inspecting Officer of the power of superintendence, be responsible for the sufficiency of the packing, marking etc. of all imported parts of the work to ensure their delivery in India without damage.

6.11 **Training**: After the signing of the contract a project team of the purchaser shall visit the contractors premises and the associated units to work out an agreement containing the schedule of training for the purchaser personnel. The time spent by the project team during the visit shall not be a part of the specialised training as indicated below and shall be free of charge.

6.12 The contractor shall arrange for the training of maintenance & operating personnel of the purchaser up to 40 man months against the supply contract, where each man month shall be of 25 working man days. The details of the training shall be worked out during contract finalisation stage/design approval stage.

7.0 GUARANTEE / WARRANTY:

7.1 The contractor shall be responsible for any defect/failure of locomotive supplied by him due to defective design, material or workmanship up to the period of i) 60 months from the date of taking over the equipment after successful commissioning or ii) 72 months from the date of despatch of material, whichever is earlier. The contractor shall replace/repair all such equipment during the guaranteed period at his own expenses.

Further, should any design modification be required to be made in any part of the equipment, the modified part should be guaranteed for 60 months and the period of 60 months will commence from the date when the modified part is commissioned in service.

7.2 The warranty for the special tools and test equipment shall not expire before 12 months from date of supply.

7.3 The warranty for the maintenance spares and unit exchange spares shall not expire earlier than 36 months from date of supply.

7.4 All replacement and repairs that the purchaser shall call upon the contractor to deliver or perform under this warranty shall be delivered and performed by the contractor within 30 days promptly and satisfactorily, by borrowing, if necessary, the components from the bank of spares as available with the purchaser.

7.5 However the contractor shall also maintain their own bank of spares at the nominated places, to be decided mutually with the purchaser, to ensure timely replacement / repairs of defective equipment under warranty obligations.

7.6 During the warranty period the Contractor shall maintain a service group in India.

7.7 Beyond the Warranty period the Contractor should be committed to support the stock for a minimum period of 20 years for spare requirements etc. If, during this period, the supplier intends to discontinue the manufacture of spares or replacement parts for the stock, advance notice of such intention shall be given by the contractor to the purchaser. In such a case, the contractor shall assist the purchaser to develop alternative sources with same technology, reliability and performance.

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8.0 APPROVAL OF DESIGN

8.1 The design shall be developed based on the requirements given in this specification and sound engineering practices. The design shall be developed in SI units.

8.2 The entire design shall be supplied by the contractor with required technical data and calculations to RDSO for approval. The manufacturing will commence after and as per the approval of design by RDSO. The details would be provided to RDSO progressively over a period of 4-6 months. Any calculation which is evaluated on the basis of software simulations shall be supported with sample calculations. Three sets of RDSO approved design are to be supplied by contractor. The actual distribution shall be finalised during design stage.

8.3 Programme for submission of design & drawings shall be furnished with the tender to enable RDSO to plan in advance. The programme shall be finalised at the time of contract finalisation.

8.4 The Contractor shall submit all necessary data, designs, calculations, drawings and specifications referred in their drawings or design documents in English language as required by RDSO for examination and shall provide explanation and clarification of the documents for which approval is sought. Approval or decision by RDSO shall normally be given within 3 weeks of submission of all clarifications by the contractor to the satisfaction of RDSO. For the purpose, the contractor shall depute its technical experts to RDSO for design discussions and finalisation. After the final design is approved the contractor shall furnish complete set of specifications and standards as mentioned in the approved drawings & documents and shall also submit the list of equivalent Indian Standards, wherever applicable.

8.5 Contractor shall submit complete design details, block diagrams, functional description of all sub-systems, schematic drawings, loading calculations, circuits, wiring diagrams, device rating & data sheets of converter, inverter and other power, control and the major equipment, loading of electronic equipment /components calculated under the ambient conditions as specified, ventilation design, component rating, structural details of locomotive, bogies suspension, FEM analyses of mechanical parts, pneumatics & brake system etc. The aspects covered above are not exhaustive and the contractor shall commit to supply / furnish complete technical details with respect to their system and equipment design and to the satisfaction of RDSO for design approval.

8.6 Deviations proposed by the contractor in the interest of reliability and better performance will be examined by RDSO in close consultation and association with the manufacturer so as to arrive at the final locomotive design.

8.7 The contractor shall submit the complete material / technical specification and sources of the components during design approval. The specification shall specifically be indicated on relevant drawings / documents.

8.8 The contractor shall furnish details of its Quality Assurance and Quality Control at the design approval stage. The quality checks to be made at various stage of manufacture, final assembly and commissioning with tolerance would be indicated. The system would also cover the quality assurance for bought out items.

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8.9 Approval of design means the approval of general design features. Notwithstanding approval from RDSO the Contractor shall be wholly and completely responsible for the satisfactory performance of the equipment. Deviations proposed by the Contractor in the interest of reliability and better performance will be examined by RDSO in close consultation and association with the manufacturer so as to arrive at the final design.

8.10 The contractor shall be responsible for carrying out improvements and modifications at his own expense on all the equipment supplied, provided such modifications/improvements are decided to be necessary for meeting the requirements of reliability, performance, safety etc. jointly between contractor and purchaser.

8.11 For the purpose of technical decisions on improvements/modifications etc. on equipment, the final authority from the purchaser's side will be RDSO.

9.0 STANDARD SPECIFICATIONS

International Electro-Technical Commission (IEC) publications and Indian Standards (IS) and Indian Railways Standards (IRS) as far as applicable and relevant to the various equipment, systems and sub-systems will be considered. The standards applicable for equipment as well as for materials will be furnished during design approval stage. In case of any conflict between the requirements of this specification and standards, the stipulations of this specification will have precedence. In case of contradictions between these standards, the same will be agreed mutually. Any deviations from these specifications as specified herein and as may be mutually agreed to subsequently between the Contractor and RDSO should not reduce reliability or decrease safety margins.

10.0 DOCUMENTATION

10.1 The Contractor will furnish as made drawings and tracings, manual of instructions for operation and maintenance of the locomotive and equipments, trouble shooting instructions and such other technical information as may be required for the maintenance and operation of the locomotives in India. A preliminary version will be supplied along with the despatch of the first locomotive of each type from the Contractor's works. Final documentation will be provided incorporating experience gained in final manufacturing phase and the first period of trials within 6 months after completion of these trials. Terms and conditions in this regard will be incorporated in the contract documents.

10.2 Operation Manual

The operation manual shall be comprehensive, easy to read & understand and should include the Trouble Shooting Directory, the equipment ratings & operating limits of installed system and control & safety features.

10.3 Maintenance Manual

The maintenance manuals shall include details of the various systems and sub-system from a maintenance and fault finding stand point, with particulars of operating parameters, tools for dismantling and testing methods of assembly and disassembly tolerances, repair techniques, lubrication details, software details and trouble shooting tools and all other information necessary to set up repair and servicing programme. Those should be

accompanied by suitable illustrations & diagram. The manual shall also include inspection / overhaul procedure and periodicity of various inspection / overhaul schedules in detail, including the tools, special tools / plants, and facilities required. The manual shall also include an illustrated parts catalogue and shall contain sufficient information to identify and requisition any part.

10.4 Clarification and amendments to the document, particularly operations and maintenance manual, as necessary during the defect liability period shall be supplied by the contractor. Updates shall be provided for the original and all copies supplied.

10.5 The operations & maintenance manuals shall be supplied @ 1 set (hard copies) per loco. All the document shall be supplied in electronic form on Compact Discs also along with software and hardware tools to read and print them. The format of electronic copies shall be proven in at least two other applications.

10.6 The manual shall be generally in A4 size and shall be bound with wear resistant covers.

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CHAPTER - 2

OPERATING & SERVICE CONDITIONS AND DESIGN CONSTRAINTS

1.0 Leading parameters of Locomotive:

Axle load	25 tonnes ± 2%
No. of axles	6
Weight	150 tonnes ± 1%
Maximum design speed	120 kmph
Test speed	135 kmph
Buffing load	Static buffing load 400 tones.
Unsprung mass	<= 4 tonnes per axle.
Lateral forces	<= 4 tonnes at the maximum test speed of 135 kmph.
Dynamic augment	<= 50%.
Maximum height above rail level for centers of buffer for unloaded vehicle.	1105 mm
Minimum clearance from rail level in fully loaded condition and with worn wheel	102 mm
Overall moving dimensions	Within dimensions shown in RDSO Drg. No. 1D placed at Annexure-A1.
Schedule of dimensions	Indian Railways Schedule of Dimensions for Broad Gauge, revised, 2004.

2.0 Power Supply System:

Nominal supply voltage	25 kV, 50 Hz, single phase, AC
Normal variation in supply voltage	19 kV to 27.5 kV
Occasional maximum voltage	30 kV
Occasional minimum voltage	16.5 kV
Normal variation in frequency	± 8% (46 to 54 Hz)
Stagger of the contact wire	± 200mm on straight track Upto 300mm on curves
Normal contact wire height in mid span (1)	5.5 m / 6.9 m
Max. contact wire height (1)	5.8 m / 7.5 m
Min. contact wire height	4.65 m

Note (1): Increased values may be applicable for the dedicated freight corridor.

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3.0 Track Parameters:

Gauge	Broad Gauge 1676mm.	
Schedule of dimensions	Indian Railways Schedule of Dimensions for Broad Gauge (1676mm). Revised, 2004.	
Sharpest curve to be negotiated	175 m radius (horizontal); 2500 m radius (vertical).	
Sharpest turnout to be negotiated	1 in 8½ turnouts.	
Maximum Super elevation	185 mm	
Maximum cant deficiency	100 mm	
Permissible track tolerances:	**BG Main Line**	**BG High Speed Route**
➢ Unevenness (3.6 m base)	< 15 mm	< 10 mm
➢ Twist (3.6 m base)	< 2.78 mm/meter	< 2.08 mm/meter
➢ Gauge variation	<± 6 mm	<± 3 mm
➢ Alignment (versine on 7.2 m chord)	< 5 mm	< 5 mm
Gauge widening:		
➢ On curves of > 350m radius	-5mm to +3mm	
➢ On curves of < 350m radius	Up to +10mm	

4.0 Climatic and Environmental Conditions:

➢ Atmospheric temperature	Under Sun : 70°C max. In shade : 50°C max. Temp. inside working locomotive may reach 55°C. Minimum temperature: 0°C
➢ Humidity	100% saturation during rainy season.
➢ Reference site conditions	i) Ambient Temp.: 47°C ii) Temp. inside loco: 55°C iii) Humidity: 60% iv) Altitude: 160 m above mean sea level.
➢ Rain fall	Very heavy in certain areas. The locomotive shall be designed to permit its running at 10 kmph in flood water level of 10 mm above rail level.
➢ Atmosphere during hot weather	Extremely dusty and desert terrain in certain areas. The dust concentration in air may reach a high value of 1.6 mg/cub. In many iron ore and coalmine areas, the dust concentration is very high affecting the filter and air ventilation system.
➢ Coastal area	Locomotive and equipment shall be designed to work in coastal areas in humid and salt laden atmosphere with maximum pH value of 8.5, sulphate of 7 mg per litre, max. concentration of chlorine 6 mg per litre and maximum conductivity of 130 micro siemens /CM

➢ Vibration	High level of vibration and shocks.
➢ Electromagnetic Pollution	High degree of electromagnetic pollution is anticipated in locomotive machine room, where the equipment will be mounted. Necessary precaution should be taken in this regard.

The locomotive equipment shall be able to start up at the maximum temperature, which may be reached inside a locomotive standing in sun, without any pre-cooling requirement.

5.0 Signal and Telecommunication Installations:

5.1 The tracks over which the offered locomotive propulsion system will work may be equipped with DC track circuits, 83-1/3 Hz track circuits as well as track circuits at higher frequencies. Similarly, other devices like axle counters, block instruments, point machines, etc., may also be employed. On the communication network, control circuits, teleprinter circuits, as well as VHF/UHF and micro-wave circuits are employed.

5.2 The harmonic currents injected in the overhead supply system (as also the track return current) can introduce voltage harmonics on power supply and can interfere with signal and telecom circuits. The design of the power electronics and control electronics provided on the propulsion system will be such as not to cause levels of interference exceeding the levels specified below at any point in the operating envelope of the locomotive:

Psophometric current	10.0 A
DC component	4.7 A
2nd Harmonic component	8.5 A
1700 ± 50 Hz component	400 mA
2000 ± 50 Hz component	400 mA
2300 ± 50 Hz component	400 mA
2600 ± 50 Hz component	400 mA
5100 ± 50 Hz component	270 mA

Emission from locomotives to outside world will be limited to level specified under CELELEC standard 50121 –2.

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CHAPTER 3
PERFORMANCE REQUIREMENTS

1.0 With line voltage of 22.5 kV AC and half worn wheels, the locomotive shall be capable of the following performance under the reference site conditions:

(i)	Starting tractive effort	Not less than 60t under dry rail condition.
(ii)	Continuous rated speed	Not more than 50 kmph.
(iii)	Max. design speed	120 kmph
(iv)	Continuous rated power at rail	Not less than 7000 kW at all speeds from continuous speed to max. design speed.
(v)	Regenerative brake	Maximum possible without skidding; over a wide speed range.

Full power shall be available in the specified range of normal variation of voltage and frequency of power supply as per clause 1.0 of chapter 3. Variation of power, if any, in the specified occasional maximum to minimum voltage range shall be specified.

There shall be no reduction in the maximum tractive effort in the maximum to minimum voltage and frequency range.

2.0 **Duty Cycle:**

The locomotive working in adverse terrain will be required to negotiate longer periods at lower speeds. The typical duty cycle encountered in operation could be as given below and loco propulsion system and equipment should be able to work satisfactorily under such conditions.

Speed	% of total running time of locomotive
0-10 km/h	05 %
10-30 km/h	10 %
30-60 km/h	20 %
60-80 km/h	50 %
80-100 km/h	15 %
100-120 km/h	No operation at present; operation is contemplated in future

3.0 **Adhesion requirements:**

The design of the adhesion control will be optimised for maximum utilisation of adhesion factor and should be such that it is capable of generating the required starting tractive effort under dry rail conditions. The contractor will state the value of maximum starting tractive effort that will be developed under dry rail conditions and also under all weather conditions, which will be demonstrated during testing. The adhesion control system will be capable of giving high adhesion through a wheel slip control system of proven performance. The objective should be to maximise the delivered draw bar pull through control system in conjunction with sanding. The achievable running adhesion characteristics will be made available. The formulae for linking adhesion characteristics with the operating speed will be indicated.

CHAPTER 4
TECHNICAL REQUIREMENTS

1.0 GENERAL

1.1 The locomotive shall be provided with proven state of the art technology that has been tried/tested in rail traction application with good level of performance and result. The details of such applications and user experience shall be provided.

The locomotive will incorporate features to yield high availability for traffic use, low maintenance requirements, easy maintainability, high reliability in operation and high efficiency.

1.2 The system and equipment should be specially adopted for application to meet the performance requirements under environmental conditions specified in this Chapter 3. Adequate margin will be built in the design, particularly to take care of condition of high ambient temperatures, dusty condition, high humidity prevailing in India. The equipment, sub-system and their mounting arrangement shall be designed to withstand satisfactorily vibrations and shocks encountered in service as specification in relevant IEC publications unless otherwise prescribed.

1.3 The cooling air for traction motors as well as for other equipments shall preferably be drawn from outside the locomotive through filters located in the sidewall of the locomotive. The design shall take care of the dusty and rainy/moist conditions prevailing in India. The system shall be designed in such a way that interval between cleaning of any filter elements shall not be less than three months.

1.4 The equipment compartment having relays, contactors, electronic control panels, etc., shall be pressurized to prevent the ingress of dust into the compartment. The pressure and flow of air will be so regulated as to provide adequate cooling to the equipments inside the compartment.

1.5 The 'tractive effort-speed' and 'draw bar pull-speed' curves shall be indicated. Each shall be drawn after making suitable correction for derating under ambient conditions indicated in Chapter-2 and with half worn wheels.

1.6 Easy access for inspection and maintenance requiring minimum attention shall be given special consideration in the design and layout.

1.7 It should be possible to use the locomotive in multiple unit operation up to 02 locomotives in one group. The entire control of both locomotives shall be achieved from the leading locomotive under multiple locomotive operation.

1.8 Provision shall be made in the control circuitry of the locomotive, to limit the starting tractive effort to predefined values when required during operation. The predefined values shall be around 30 ton /60 ton per locomotive or more, to be decided during design stage.

1.9 Provision shall be made to enable operation of locomotive under inching control mode, i.e., at a very small constant speed set by driver irrespective of the load, gradient, curvature of

track etc. It shall be possible to change from inching control mode to Normal Mode and vice versa by the driver depending upon his requirement.

1.10 The locomotive shall be provided with a synchronous control system through wireless signals between locomotive or locomotive consist at the front, in the middle or at the rear end of train formation for operation of heavier and longer trains. For this, all the control and operating signals from the lead locomotive shall be transmitted to the distributed trailing locomotives through radio transceiver, so that all of them are run in synchronization with a single driver control from the lead locomotive. Encryption shall be provided for commands sent from the lead locomotive and feedback messages from the trail locomotives for security purpose. The display shall indicate the status feedbacks received from the trailing units. At any time, it shall be possible to view the status of all trailing locomotives from the leading locomotive by the driver. In the trailing locomotives, train Lines shall be driven based on the commands received from the leading locomotive. Interface shall be provided for Air brake control in the trailing locomotives, from the commands from leading locomotive. It shall be possible to use any locomotive fitted with this system in leading or trailing position.

1.11 The locomotive shall be provided with speed control system, which enables to pre-set the speed at which it is desired to run the train irrespective of the track profile.

1.12 As far as possible, a unit system of having a complete block of associated traction motor, Power converter, control circuits, etc., may be adopted so that a minimum possible equipment set can be cut-out in the event of faults.

1.13 In the vital units of the power control circuit, where any defect/failure of a component would cause complete failure of locomotive's electrical system, suitable redundancy/duplication may be provided preferably with automatic substitution features to avoid locomotive failure or drastic reduction in performance due to such defects.

1.14 The protection/alarm/indication circuits should normally have self-correcting features rather than cause tripping of the locomotive or drastic reduction in tractive effort. If Driver's intervention is needed, sufficient time/advance indication should be made available to the Driver to enable corrective action to be taken in time.

1.15 In design and construction, reliability and maintainability will be of paramount consideration. Tenderer will submit reliability calculations indicating MTBF for different devices, cards and sub-assemblies. Adequate margin will be provided to take into account ambient conditions prevailing in India.

1.16 High efficiency of equipment will be important consideration, next only to high reliability. The components and technology used shall ensure very high efficiency of the converter. Tenderer shall furnish the expected efficiency with respect to vehicle load and speeds.

1.17 Modular constructions will be adopted wherever considered possible. Easy access for inspection/maintenance and minimum maintenance requirement will be given special consideration in design and layout. In this reference, the scheduled maintenance activities shall be a part of design documents and have to be got approved along with design approval.

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track etc. It shall be possible to change from inching control mode to Normal Mode and vice versa by the driver depending upon his requirement.

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1.14 The protection/alarm/indication circuits should normally have self-correcting features rather than cause tripping of the locomotive or drastic reduction in tractive effort. If Driver's intervention is needed, sufficient time/advance indication should be made available to the Driver to enable corrective action to be taken in time.

1.15 In design and construction, reliability and maintainability will be of paramount consideration. Tenderer will submit reliability calculations indicating MTBF for different devices, cards and sub-assemblies. Adequate margin will be provided to take into account ambient conditions prevailing in India.

1.16 High efficiency of equipment will be important consideration, next only to high reliability. The components and technology used shall ensure very high efficiency of the converter. Tenderer shall furnish the expected efficiency with respect to vehicle load and speeds.

1.17 Modular constructions will be adopted wherever considered possible. Easy access for inspection/maintenance and minimum maintenance requirement will be given special consideration in design and layout. In this reference, the scheduled maintenance activities shall be a part of design documents and have to be got approved along with design approval.

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1.18 Semi conductor devices rating will be selected so as to provide margin of 25% vis-à-vis design/calculated current and voltage values under worst operating conditions after taking into account voltage jumps and current surges on account of inductance and capacitance in the circuit.

1.19 The design calculations of worst case temperature rise of equipment shall be made after taking into account 25% choking of filters and heat sink/radiator fins. A safety margin of at least 10°C shall be kept with respect to maximum permissible junction temperature of power devices declared by the manufacturer.

2.0 ELECTRICAL

2.1 Pantographs:

2.1.1 The locomotive shall be equipped with two pantographs. Normally the trailing end pantograph shall be used. The pantograph selector switch shall be provided in the Driver's desk for raising either of the pantographs or both the pantographs at a time. Raising or lowering of pantograph with locomotive in motion will not cause any undue disturbance to OHE.

2.1.2 It would be possible for each of these pantographs to be disconnected from roof equipment and earthed in case of damage.

2.1.3 The wearing strips to be used on the pantographs shall be proven design/material such as will cause least wear on the overhead contact system as well as to the strips themselves. Strips other than steel may be offered for this purpose if considered suitable for application under Indian condition.

2.2 Main Circuit Breakers:

Vacuum circuit breaker of proven design shall be provided.

2.3 Lightning Arrestor:

A gapless type lightning arrestor of well proven design shall be provided on the roof of the locomotive for protection against the line voltage transients caused by lightning or system switching.

2.4 Main Transformer:

2.4.1 The fixed ratio main transformer shall be provided with multi-traction windings suiting the requirements of Power Converter adopted, and an auxiliary winding for supply to auxiliary machines.

2.4.2 The kVA rating of the transformer shall be specified at a line voltage of 22.5 kV and shall be designed to deliver a total current corresponding to the continuous rated traction motor currents at full voltage. The transformer traction winding shall also be designed to deliver the rated current at the maximum line voltage of 27.5 kV.

2.4.3 The transformer shall be designed with adequate overload capacity to permit full utilization of the traction motor capacity during the starting as well as running.

2.4.4 The transformer shall be designed to conform to IEC:310 and the temperature rise limits on the windings and the oil shall correspond to IEC:310 limit minus 20°C under all conditions of operation.

2.4.5 The transformer shall be oil immersed and forced oil cooled by means of an oil circulating pump and a radiator. The oil cooler (radiator) shall be air blast cooled by means of a motor driven blower set. Means shall be provided for letting out the oil from the transformer through the floor to the underside of the locomotive, in the event of any fault/electrical disturbance in the transformer causing oil to rush out.

2.4.6 The chokes and inductor in the main power circuit shall be oil cooled. The cooling circuit will be common with that of main transformer.

2.5 Power converter

2.5.1 In the design and construction of IGBT Thyristor converter/inverter and associated control equipments, reliability and maintainability are paramount considerations. Adequate margin shall be provided to taken into account conditions prevailing in India. Freedom from dust and protection from surges shall be ensured. Modular construction shall be adopted wherever considered possible for achieving the above requirements.

2.5.2 The voltage rating of IGBT would be so chosen that at least 25% margin is available after taking into consideration the DC link voltage and voltage jump on account of inductance and capacitances in the circuit. The current rating of IGBT shall be such that the junction temperature has the minimum thermal margin of 10°C in the worst loading conditions and under the ambient conditions as specified.

2.5.3 The wheel slip detection and correction system shall be an integral part of the control system of the Power converters/inverter and shall supervise excessive acceleration, differential speeds between axles, over speed and any other parameter considered necessary to maximize adhesion and minimize wheel slipping / skidding.

2.5.4 The converter will be designed and operated to achieve near unity power factor and minimum harmonic interference current. The input power factor shall be settable close to unity within the line voltage range from 19 kV to 27.5 kV at all speeds of operation of the locomotive. The maximum interference current permitted is specified in chapter 2 of this specification.

2.5.5 The converter/inverter system will be capable of withstanding the maximum short circuit current under fault conditions and these will be established through calculations. The converter / inverter system shall also be designed to withstand extreme disturbances like short-circuit / open circuit etc. at all points of input / output interfaces with locomotive, without any failure. This will be demonstrated during prototype tests as per the relevant clause of the IEC.

2.5.6 Following special features will be provided to maximise the performance & reliability and minimise possibilities of trains being stalled on the section:

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(a) Individual and independent inverter will be provided for each TM / axle and design should be such that one Inverter / TM / axle can be isolated in the event of fault on a TM or an inverter and train worked with remaining TMs. The adhesion control system will also be optimised for the individual axle drive. Wheel diameter difference permissible on different axles will also be liberal.

(b) Suitable redundancy will be provided in the vital PCBs connected with safety and power supplies, so that locomotive failure, degradation in performance and disabling the train is avoided in the event of their failure.

2.5.7 The motor converter output current ripple should be such as to keep the torque pulsations and traction motor heating to a minimum. It is the contractor's responsibility to make sure that output quality of the Traction Converter is entirely suitable for the existing traction motors.

2.6 Traction Motor

2.5.1 The general design and manufacture of the motor shall be of the highest standard in accordance with the modern traction practices. The design shall include all those features, which are known to have worked well in the tropical climatic conditions.

2.5.2 The motor will be liberally rated as per the loco performance requirements for the 'most severe normal service' as defined vide clause 2.2(a) of IEC: 563-1976.

2.5.3 The motor shall be designed so as to be capable of withstanding transients such as line voltage fluctuations, switching surges and such other conditions caused by stalling and wheel-slips under different operational conditions.

2.5.4 The following operational and environmental factors will be specially kept in view in the design of the motor:

- Excessive vibration that are experienced because of average track maintenance conditions in India.
- Prevalence of high temperature and humidity for the most part of the year.
- Operation of the loco over a long country terrain in which the climate will vary from excessive dry heat on one end to high humidity on the other end or during winter months from very cold to moderately warm and humid conditions on the other end.
- Operation under highly dusty environments.

2.5.5 In determining the ratings, design parameters and construction of the traction motor, full consideration shall be given to the duties imposed by requirement of regenerative braking.

2.5.6 Insulation System:

- The insulation system to be employed shall be particularly designed to withstand the adverse environmental conditions. The materials comprising this system and the system itself shall have been proved to be of the highest reliability in traction application. Imperviousness to moisture will be a special requirement.
- The evaluation of the insulation system for thermal endurance shall be made with fabricated test models by way of accelerated ageing tests as per the test programme

drawn up in accordance with the norms specified in IEC: 505/1975, IEC: 505 Draft supplement and IEEE-304.

- Evaluation of insulation system for sealing against moisture shall be done in accordance with IEEE-429.
- Various ageing parameters, such as heat, vibration, mechanical/compressive stresses, special environmental effects of humidity, dust, metallic dust from brake shoes, etc., will be incorporated to simulate the actual working conditions as closely as possible.
- The temperature at which an extrapolated life of 20,000 hours is obtained shall be treated as the thermal endurance limit (Temperature Index) of the insulation system.
- The motor shall be designed such that the "hot spot" temperature under any condition of loading in any winding (armature or field) does not exceed the average temperature of that winding measured by resistance method, by more than 15°C.
- Having regarding to the system of insulation adopted and the environmental conditions, the manufacturer shall provide maximum possible margins in temperature rise, for prolonged life of the traction motors.

2.5.7 The mechanical design of the motor, fixing arrangement on the bogies, the gears and pinions, gear case, etc. shall receive particular attention.

2.5.8 Harmonic/Ripple factor:

The traction motor shall operate satisfactorily over the entire range of loading, with harmonics/ripples imposed from the supply system, (comprising transformer, converter, inverter, etc.), both during motoring and regenerative braking conditions. The manufacturer shall conduct necessary tests on the traction motor to establish compliance with this requirement.

2.6 Auxiliary Systems:

2.6.1 Only a few different types of motors will be used to guarantee interchangeability. Coupling and mounting design requirements will be kept identical where applicable. Adequate redundancy shall be maintained while selecting the size of motors.

2.6.2 The supplier shall indicate total horse power required for auxiliaries with break up of power requirement for each of the auxiliaries at rated output. The supplier shall indicate the method used for determining power requirement for each auxiliary. In case these are measured values, the supplier shall furnish detailed method employed for measurement of auxiliary horse power.

2.6.3 The power supply for the auxiliaries shall be through solid-state converters of proven design. The auxiliaries shall be driven by 415 V 3-phase AC motor except for auxiliary compressor motor (baby compressor) which is to be rated at 110V DC, all the remaining drive motors shall preferably be designed for three phase AC supply with suitable protection. All the drive motors will be designed for three phase AC supply with suitable protection against single phasing and short circuits.

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2.6.4 Totally enclosed fan cooled design is to be considered for auxiliary machines if the use of such machines is likely to result in freedom from dust and contamination and in general better performance. Internally ventilated auxiliary machines having encapsulated stator windings may also be considered for this application if considered to be advantageous over totally enclosed fan cooled design.

2.6.5 The temperature rise limits for auxiliary machines will be reduced compared to IEC limits to take care of the higher ambient in India. Only insulation system of class H and higher will be acceptable. The permitted temperature rise for different classes will be:

Class H - 80°C
Class C - 100°C

Vacuum pressure impregnation of the stator winding must be done using solvent less varnish having thermal index above 200°C.

2.6.7 In the case of squirrel cage motor, aluminum alloy die cast rotor construction is preferred.

2.6.8 L-10 life of bearings when calculated as per ISO Recommendation R-281 shall not be generally less than 100,000 working hours. For motors higher than 15 kW, flange bearing housing units shall be preferred. The bearing design shall be such that no greasing or any intermediate attention may be required to be done for at lest one year after each greasing/adopting maintenance schedule as recommended by manufacturer.

2.6.9 **Auxiliary Compressor Set:** A 110 volts DC battery operated auxiliary compressor set having a minimum capacity of 150 litres per minute at the rated rpm, shall be provided for feeding the auxiliary air reservoir for operation of the pantograph and air blast circuit breaker (if provided), during the preparation of the locomotive for service. A suitable governor device shall also be included.

2.6.10 **Battery and Battery Charger:**

- Rechargeable batteries of adequate capacity shall be provided on the locomotive to feed the equipment for at least 5 hours in the event of a failure in the battery charging system. The battery shall also be capable of feeding the headlight through inverter/chopper during catenary supply failure.
- The battery will be Nickel-Cadmium type.
- An automatic static battery charger, having rating and charging characteristics matched to the battery shall be provided.

2.7 Electronics, Control and Communication:

2.7.1 The electronics used on the locomotive shall conform to IEC-60571 including compliance to the optional tests. However, due to higher ambient temperature in India, it shall be suitable for dry heat test at 80°C. The electronic control equipments should be protected against unavoidable EMI in the machine compartment.

2.7.2 Control and communication shall be based on open control architecture and compliant to IEC-61375 "Train Communication Network" protocol. The programmable devices should be programmed using language compliant to IEC-61131.

2.7.3 It is desirable that the majority of control and monitoring function is implemented by software so as to reduce hardware and cables.

2.7.4 The control system shall integrate the task of fault diagnostics and display in addition to control task. It should be capable of real time monitoring the status of all the vital equipment continuously and occurrence of faults. It should also take appropriate protective action and shut down the equipment wherever necessary.

2.7.5 Features of self-check, calibration and plausibility checks must be incorporated in the design.

2.7.6 Adequate redundancy should be built-in with the design in order to improve reliability and availability. The offer should clearly spell out the redundancy concept.

2.7.7 The vehicle control unit (VCU) should have a diagnostics computer, with non-volatile memory, to store all the relevant diagnostic data. On occurrence of each fault, besides the fault information on equipment parameters, background data with time stamp shall also be captured and stored with a view to enable proper fault analysis. There must be facility to capture post trigger and pre-trigger background information. Application software shall be provided to facilitate the fault diagnosis and the analysis of equipment wise failures.

2.7.8 It should be possible to access all the processors within a vehicle and also the same in other vehicles in a train formation using a standard laptop connected to one of the ports provided on the VCU rack. Such access is needed for uploading of firmware/application program, visualization of process parameters and also force or record the same and downloading the diagnostic data. Required interfaces should be built in the VCU so that standard laptops can be directly plugged to the VCU without any special interface. Supply of a suitable software tool is included in the scope. Using this tool, it should be possible to reset the diagnostic memory for further recording. This tool must also provide detailed off line analysis facility.

2.7.9 It should be possible for the Railways to execute parametric changes in the software in respect of user's interface viz; modifying some of the permissible parameters for adjusting the characteristic within permissible range, add/alter the protection features, if so required in future in order to improve the operation of locomotive. Contractor shall provide all necessary equipment and accessories required for the purpose.

2.7.10 The electronics shall be designed to be sealed from the remaining part of the machine room so as to ensure that there is no dust ingress whatsoever in to the electronics. For its cooling, internal ventilation arrangement along with heat exchanger for removal of heat shall be provided. Temperature difference between inside of the electronics cubicle and the Machine room shall not be more than 10°C.

2.7.11 Use of Application Specific Integrated Circuits (ASICs) must be avoided. Circuit Boards must use general purpose ICs to the extent possible.

2.7.12 The electronic cards shall be mechanically coded to ensure that insertion of card in wrong slot is not possible.

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2.8 Control Equipment:

2.9.1 All necessary control equipment including driver's controls and indications for electrical, pneumatic, air pressure, brake and other circuits, shall be provided. Necessary operational, protective and safety devices in the form of relays, contactors, switches as may be required by circuit design shall also be incorporated for the proper functioning of the power and auxiliary equipments, brakes etc.

2.9.2 The control equipments, relays and switches, and such other devices shall represent the latest and proven technology established under the most severe operating conditions, with particular regard to reliability. The use of relays and contactors shall be to bare minimum.

2.9.3 Wherever considered necessary, contacts shall be duplicated to provide redundancy.

2.9.4 Interlocks and auxiliary contacts with important protective, operation, control, auxiliary and safety circuits shall be housed in dustproof 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.

2.9.5 The working of all relays and contactors shall be satisfactory up to a minimum control voltage of 70V DC (corresponding to a nominal battery voltage of 110V dc) when the operating coils are at their rated temperature and the contacts are subjected to normal pressure.

2.9.6 Rubber components, such as pistons, 'O' rings etc. wherever employed in control gear (and brake system and their controls) shall be entirely suitable for humid and environmentally unfriendly conditions in India.

2.9.7 Surge suppression circuits shall be incorporated, wherever required.

2.9.8 Capacitors shall be liberally rated, keeping in view the high ambient in India, vibrations of electric rolling stock and electrical surges expected during operation.

2.9.9 Special endurance tests may be required to be conducted-both-mechanical and electrical-to prove the reliability of the control equipments used.

2.9 Master Controller:

A Master Controller of proven design shall be provided in each cab. It will be integrated with stepless traction / braking lever, forward/reverse switch, cab activation switch etc. In the design of the driver's controls, the following aspects may be kept in view:-

(i) It should not be possible for unauthorized persons to operate the master controller.

(iii) The reverser handle shall be so inter-locked that master controller handle can move only when the reverser is placed in an operative position. Conversely, it shall be necessary for the master control to be returned to the off position, before the reverser handle can be returned to the OFF position.

(v) Interlocks with braking system shall be incorporated in the master controller.

(vi) Traction should be possible only from one cab at a time.

(vi) Provision shall be made to ensure unhindered operation in case of failure of Master Controller

2.10 Driver's Display Panel:

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A suitable LCD display (back lit) or other better arrangement with robust and heavy duty input/output system shall be provided on driver's desk to display fault status, energy values and status of various important parameters as selected by driver maintenance staff or as required for the satisfactory system operation. The selection of the display panel shall be liberal and details shall be worked out during design stage. Contractors shall furnish further options available. The display system shall be protected against dust and moisture.

2.11 Instruments and Gauges:

2.11.1 Instruments and gauges provided shall include ammeters for traction motor current and volt-meter for traction motor voltage and Line voltage along with other necessary instruments.

2.11.2 The possibility of providing indication of availability of OHE power supply, through capacitive coupling means, without raising the pantograph may also be considered and included.

2.11.3 For prototype locomotives, it shall be required to carry out instrumentation for measurement of energy power, currents, and voltages at various circuit points.

2.11.4 Locomotives shall be provided with energy meter.

2.12 Wiring and Cabling:

2.12.1 The cables for wiring in the locomotives and equipments shall use high grade electrolytic copper stranded conductors tinned as per approved international practice and standards.

2.12.2 The cables shall be of approved quality and grade of insulation and sheath. They shall be fire retarding type. In locations where high temperatures are likely to be met, special cables may be employed.

2.12.3 All connections shall be terminated on terminal bars of approved design, provided for the purpose. The terminals and wire cable ends shall be suitably marked to facilitate correct connections.

2.12.4 Plugs/Couplers and sockets will be used to connect pre-assembled units to facilitate maintenance and ensure a better layout.

2.12.5 No cable having a conductor size of less than 2.5 sq. mm shall ordinarily be used. Smaller size cables for internal wiring panels, control cubicles, consistent with the mechanical and electrical requirements, may be adopted.

2.12.6 The layout of the cables shall be such that contamination by oid is avoided. Length of power cables should be kept to minimum. Cables and connections carrying different types of voltages shall be physically segregated from each other. Adequate numbers of standby vital spare control wires should be provided with adequate indications.

2.12.7 Loading of Power cables shall not be more than 75% of its capacity.

2.13 Lighting:

2.13.1 The lighting equipment (cab lights, reading lights, corridor lights, head lights, marker lights, flasher lights etc.) shall normally be based on 110V DC battery supply. Gauges and instrumented lamps to illuminate the dials, shall work at 24V. Adequate number of gauges with self-illuminating gauge lights, preferably light-emitting diodes shall be fitted.

2.13.2 Head Lights

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At least two headlights should be provided at each end, working on 24 V halogen lamps having two filaments. Headlight units should be pre-focused capable of giving 3.2 LUX at a distance of 305 meters. The design should provide for easy replacement of bulb. Arrangement should be made for dimming the headlight output when required.

2.13.3 Marker lights

Locomotive shall be provided with two numbers of red and two numbers of white marker lights on each end. Being safety item, the marker lights should have LED lighting source with very high reliability and long life. They should be provided in suitable water-proof enclosures (IP 65) and window toughened front glass. Each unit should produce at least 75 LUX at a distance of 1 meter and 7 LUX at 3 meters. The clear visibility of marker lights shall not be less than 2 kms. at night.

2.13.4 Flasher Lights

Two flasher lights, one at each end of the locomotive, shall be provided. It will be designed to provide 40 ± 5 flashes per minute. It should emit sufficiently bright Amber-yellow light with dominant wavelength of 590-595 nanometer to be visible at a distance of 2 kms. in clear daylight and not be affected by sunlight glare. The LUX measured in axial direction shall not be less than 500 LUX at 1 meter and 55 LUX at 3 meters. These shall work off battery supply. These flashers will be used in emergencies arising from accidents to trains, etc.

Facility for monitoring and positive confirmation whether flasher light is lit or not shall be provided in form of audio-visual indication in driver cabs.

The working of the flasher lights should be so integrated with the train brake system that in the event of train parting, flasher light shall get automatically turned ON and any tractive effort on locomotive shall be disabled until acknowledged by the driver. Detailed design shall be finalised during design approval.

2.14 Speed indicating and recording equipment:

The locomotive shall be provided with speed indicating-cum-recording equipment in one cab and speed indicating equipment in other cab. The speed indicating/recording equipments with electrical/electronic type of drive having scale range of 0 to 250 kmph shall be used.

2.15 Driver's Display:

.1 Display units for driver shall be provided in each cab on driver's desk displaying important information relevant to the driver, such as operational aspects, fault status / messages etc. The display will be menu driven. The interface with the driver should be very simple considering average level of proficiency of drivers in handling electronic devices.

.2 The display shall be designed to provide full guidance and assistance to driver about action to be taken in case of fault. The interface will be user friendly and there should normally not be any need for a separate Trouble Shooting Directory for driver's use.

.3 Selection of display medium should take into account high ambient temperature and light , due to direct sunlight on the driver's desk. Backlit arrangement should be provided for night visibility. The display system shall be protected against dust and moisture.

2.16 Insulating materials:

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In selecting materials of insulation, the moist tropical weather conditions prevailing in India shall be kept in view. In this regard, the manufacturer shall furnish full information regarding the suitability of the selected materials under various climatic conditions referred to in this specification. Additional necessary tests, if any, for ensuring suitability of materials shall be conducted by the manufacturer in the presence of Indian Railway's representative and the test results advised to the Purchaser.

2.17 Safety measures:

Standard protective systems for protection of the electrical equipments against abnormal currents, excessive voltages, etc., as well as indication of normal and abnormal conditions so as to ensure safe and correct operations shall be provided. While working in multiple, the faults in the trailing locomotives should be indicated in the leading loco.

All equipments 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 equipments and safety of those concerned with its operation and maintenance.

A sensitive reliable protection arrangement against earth fault shall be provided. Locomotive control couplers shall be duplicated to ensure reliability of operation.

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 a portion of an earth return circuit.

Fire prevention measure:- The design of equipment shall incorporate all measures to prevent fires and shall be such that should any fire take place, the effect should be minimized and no spread of fire should take place. Materials, which are not fire-retardant, shall not be used. The locomotive shall be provided with suitable and preferably automatic fire detection and extinguishing equipment of proven design, which can be operated manually.

The locomotive shall be provided with a manually operated two position earthing switch. The operation of the switch shall enable earthing of the power circuit of the locomotive and attention to the HT equipments by releasing interlocked keys from a box fitted to the earthing switch.

All safety features in the matter of design construction and materials used shall conform to the best safety standards and shall in particular prevent fires in locomotives. However, fire detection and extinguishing system may be provided as per current practices.

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3.0 GENERAL MECHANICAL DESIGN

3.1 The locomotive shall be of simple but modern design with relatively smooth exterior to reduce wind resistance/drag to a minimum. The overall dimensions of the cab shall take full advantage of the maximum moving dimensions prescribed. Major mechanical components shall be designed for a life of 40 years.

3.2 The general layout of the equipment in the locomotive shall ensure equitable weight distribution. The tolerance in working order will be limited to ± 2 % for Axle load and ± 1 %

for total loco weight. Difference in weight on the wheels of the same axle not to exceed 4 % of particular axle load. Method for wheel/axle load adjustment to meet the above requirements should be indicated.

3.3 Provision will be kept in the design to enable ballasting of the locomotive so as to increase the axle load to 30 tonnes, if so desired by Indian Railways. The contractor shall indicate the scheme to be adopted for increasing the axle load.

3.4 Adequate safeguards such as anti-collision post and anti-climbing bars should be provided to minimize damage to the locomotive and personnel during collision/derailment.

3.5 Draws and Buffing Gear:

The locomotive shall be equipped with high tensile automatic center buffer coupler with AAR "E" type coupler head and with AAR "F" type shank and AAR "F" type yoke. It shall conform to AAR specification No. M-211 with grade E steel. The gathering range of coupler shall be sufficient for proper functioning of the coupler including locking on curves of 174 m radius and 1 in 8-½ turnouts. The coupler shall be located at the height of 1090+15/-5 mm from rail level. Vehicle draft gear capacity and performance shall be compatible with the design buff and draft forces prescribed by the purchaser.

3.6 Wheel, Axle & Axle Journal / Axle Box Roller Bearing

.1 Wheel:-

(i) Monobloc wheels of solid one-piece multiple wear type made of heavy-duty steel conforming to IRS specification No. IRS R-34 (latest revision).

(ii) The wheel should be designed for the specified axle load and dynamic augmentation of 100%.

(iii) Wheel Tread diameter of 1092+3/-0 mm (in new condition) shall be provided.

(iv) Heat capacity of the wheel shall be 35 kW minimum.

(v) The distance between the back faces of the wheels shall be 1596+0.5/-0.5 mm.

(vi) Thick flange profile as shown in drawing no. CSL-3040 placed as Annexure-A2 shall be provided on all wheels.

(vii) Wheel drawing with all detail dimensions, Finite Element analysis report (along with boundary conditions), Pressing load calculation of the wheel during pressing on the axle and other wheel related calculations shall be supplied.

(viii) Dynamic balancing as 75 gm-m maximum residual imbalances of wheels shall be done.

(ix) A minimum wear limit of 86 mm on diameter will be provided.

.2 Axle:-

(i) The axle material shall conform to IRS specification no. IRS R-43 (Rev. latest).

(ii) The design shall take into account the type of roller bearing axle boxes to be provided.

(iii) Axle drawing with all detail dimensions shall be supplied. Hollow axles are not acceptable.

(iv) Stress calculations for axle shall be supplied.

(v) The axle should be designed for a load of 25 tons. Dynamic augmentation of 50% of the vertical journal load shall be used in calculating the axle stresses in addition to the vertical and horizontal forces and moments.

.3 Axle journal / axle box roller bearing:-

(a) Suppliers are free to incorporate any type of roller bearing supplied by any manufacturer approved by UIC/AAR to cater for the axle load prescribed under dynamic loading conditions and track geometry indicated in Chapter-2, indicating reasons for their preference for the particular type and make and acceptable to RDSO.

(b) Static and dynamic load rating, safety factor and L10 life calculation based on ISO: 281 & ISO:76 should be given. Value of all parameters required for detailed calculation need to be provided.

(c) Maintenance schedule requirements and frequency, special equipments required for maintenance skill should be indicated in the maintenance manual.

(d) Type of grease and quantity for initial filling should be indicated in the maintenance manual and periodic interval for greasing should not be less than six years.

(e) The design of the labyrinth seal shall be such as to prevent the ingress of dust into the axle boxes or the outflow of grease from the axle boxes.

3.15 Underframe:

Design of the underframe/body shall be made to safely withstand each one of the following loading conditions while carrying its loads:-

(i) Multiple unit operation with 200t load applied at the center buffer couples, and allowing for an increase of not less than 50% in the static vertical load to cater for dynamic augment encountered in service.

(ii) Lifting of the locomotive at one end of the headstock with the adjacent bogie suspended from the underframe and the other bogie resting on the rails/ground representing the conditions during the re-railing operations after an accident.

(iii) Lifting the entire locomotive including the bogies at the jacking pads.

(iv) Lifting the entire locomotive without the bogies at the buffer beams.

(v) Stationary locomotive under a squeeze load of 400t applied at the center buffer coupler.

The design shall be such that the maximum permissible stresses shall not exceed endurance limit of the material for loading conditions at (i) and 90% of the yield point stress of the material under conditions. Provision for lifting the body shall be provided. It should be possible for bogies to be lifted along with the body when required.

3.16 Bogie:

3.16.1 The suppliers are free to offer their own design of bogie provided it meets the general guidelines described below:-

(i) The bogie shall be of a proven design, maintenance friendly and capable of running upto a test speed of 135 kmph. The bogie shall be provided with two stage suspension, suitable damping both in lateral & vertical modes and controlled guidance of axle. The bogie design

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should be track friendly, with suitable arrangements to ensure minimum wear to wheels & track with minimum angle of attach. If bogie is provided with pedestals, the pedestal and axle box wear liners should be non-metallic wear resistant self-lubricating material.

(ii) The bogie shall be so designed that in normal running condition, the stresses at critical locations are always within the endurance limit of the material employed.

3.16.2 The manufacturer shall submit detailed calculations to indicate that the locomotive shall be suitable for running at a test speed of 135 kmph on the high speed routes mentioned in chapter2. Details of vehicle Dynamics model and assumptions made should be furnished along with results on straight track, 2° curved track, 1 in 8½ turnout and switches.

3.16.3 The bogie shall be subjected to static and dynamic load testing (10 million cycles) as per UIC standards. The bogie shall not show any sign of deformation/development of cracks during the above tests. The stress values should remain preferably within endurance limits except 2g & 3g casers where it should be restricted to yield stress limit.

3.16.4 The details and calculations about the load transfer from underframe to bogies along with mounting arrangement shall be provided.

3.16.5 Calculations for determining spring characteristics and the damping value in various modes should be submitted.

3.16.6 The helical springs, if used shall be of the best quality and shall be designed and manufactured for maximum fatigue life. Spring stresses under conditions of maximum dynamics augment should be within endurance dynamic limits of the spring material. The springs shall be painted with suitable anti-corrosive paints. Details of design, material, manufacturers and testing procedure shall be furnished.

3.16.7 Finite Element Analysis report of bogie frame along with its 3D model (both soft & hard copy) shall be provided. Complete bogie with all detailed drawings shall be provided.

3.16.8 Maintenance Instructions for the bogie shall be provided.

3.7 Braking requirements and Brake equipment:

3.7.1 The locomotive shall be fitted with computer controlled straight air-brake system with data logging and self diagnostic feature, which the supplier shall get approved from RDSO in advance. The brake system should be of a design, which is proven in service on adequate no. of locomotives on one or more Railways of the world. The brake system shall be compatible with trailing stock fitted with twin pipe gradual release air brake system in accordance with RDSO specification No. WD.02-ABR-84.

3.7.2 The locomotive shall be provided with self-lapping type independent brake valve with a simple arrangement of adjusting the maximum brake cylinder pressure. Corresponding to this pressure, the total braking effort shall work out to about 20% of the adhesive weight of the locomotive. The number of locos required for holding, with application of loco brakes only, 7500 tons trains on 1 in 80 and 1 in 100 gradients, with trailing stock brakes fully released, may be stated.

3.7.3 The automatic brake valve shall be of self-lapping type and shall have 'Release' and 'Run' positions as per UIC code. The 'Release' position shall be spring-loaded.

3.7.4 Provision of isolating position in the driver's brake valve will be preferred.

3.7.5 The direction of rotation of driver's automatic and independent brake valve handles shall be in an anticlockwise direction on the horizontal plane or towards the driver on the vertical plane for 'Application' of brake.

3.7.6 It shall be possible to release locomotive brakes when the brakes of trailing stock are applied partially or fully through drivers automatic brake valve.

3.7.7 Locomotive shall be fitted with digital air flow measuring and indicating devices to provide indication to the driver about level of leakage from brake pipe. In case of train parting during run, flasher light shall be automatically switched 'ON'.

3.7.8 In case of parting between the coupled locos the brakes on the locos shall come on automatically. It shall also be possible to apply independent brakes on the leading loco in case of parting.

3.7.9 Emergency brake valve shall be provided for direct opening of air brake pipe during emergency by the driver assistant, in addition to independent and automatic brake valves. During emergency brake application by emergency brake valve or through driver's automatic brake valve, automatic locomotive power cut off shall take place.

3.7.10 In the event of failure of electrical regenerative brakes while operating a train, the brakes on the train and the locomotive shall be applied automatically to prevent any speed surge.

3.7.11 It shall be possible to apply simultaneously regenerative and pneumatic brakes on the locomotive to obtain a constant braking effort corresponding to about 20% of the adhesive weight of the locomotive. This shall be achieved by automatic blending of regenerative and pneumatic brakes. Arrangements for automatic reduction of brake power during skidding of wheels shall be provided.

3.7.12 Two 32 mm dia. pipes for twin pipe air brake system shall run from end to end of the locomotive, terminating below each buffer beam of locomotive.

3.8 Brake Rigging:

3.8.1 All wheels of the locomotive shall be provided with either tread or disc brakes with high composition brake blocks. With full brake pressure, the total force on the brake shoes shall be around 80% of the maximum designed weight of the locomotive in working order. Means shall be provided to permit variation in this brake power above or below 80%. The system shall include a suitable device for taking up slack etc.

3.8.2 Detailed calculations for the brake power along with brake rigging diagram shall be submitted.

3.8.3 Adequate safety straps shall be provided below the moving components of brake rigging to prevent fouling of the track in the event of failure of any component.

3.8.4 An effective parking brake shall be provided to operate on all the wheels of at least one bogie. If the parking brake mechanism employs gears, screws, chain pulley or similar items, the mechanical efficiency shall be taken as 60% with a hand force of 25 kg. Applied on the hand wheel lever.

3.8.5 Detailed calculations for the brake power along with brake rigging diagram as per IR requirement shall be provided.

3.8.6 The brake shall have suitable device for taking up alack automatically.

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3.8.7 Brake system / rigging shall be so designed that brake application, if required for wheel slip correction, shall take place on the affected wheel pair only.

3.9 Compressed air system:

3.9.1 Compressor:

The capacity (free air delivery) of air compressor system shall be at least 3500 lit/min at 10 kg/cm sq. pressure. Two separate compressor units of capacity around 1750 litres/min. each, shall be preferred. The compressor shall be suitable for continuous operation at a pressure of 10 kg/cm sq. (without causing high temperature, damage and unusual wear of components) with governor setting to cut out at kg/cm^2 and cut in at 8 kg/cm^2 and safety valve setting of 10.5 kg/cm^2. The temperature of air at the inlet of first main reservoir shall not be more than 40°C above ambient air temperature at a pressure of 10 kg/cm sq. The compressor(s) shall be driven by dedicated electric motor(s). One or two identical units may be offered, depending on capacity. The compressor shall preferably be of underslung type. The offered design should be proven in service on adequate no. of locomotives (preferably 100 or more) on one or more Railways of the world.

3.9.2 Air Dryer:

Locomotive shall be provided with desiccant type heatless air dryer/other suitable device to provide dry compressed air to loco brake system and pneumatically operated auxiliaries.

3.10 Sanding:

3.10.1 Pneumatic sanding gear of adequate capacity shall be provided for all the wheels and it shall be effective in either direction of travel. Automatic sanding arrangement during wheel slipping by means of wheel slip detection system shall be provided. The sanding shall be direction selective.

3.10.2 Sand pipe nozzles shall be located at a distance of 45 mm from rail level and the height shall be made adjustable to cater for the wheel wear.

3.10.3 The sand boxes shall preferably be at underframe level and shall be easily accessible for filling from outside. Large capacity sand boxes shall be provided so as to last entire journey

3.10.4 The sand box lids shall be so designed as to avoid water entering the boxes and to prevent clogging of the injector inlet in the box.

3.10.5 The sanding gear shall be capable of functioning properly in the tropical humid climate where the sand does not remain dry and also gets moisture from compressed air.

3.11 Horns:

Dual tone pneumatic horns shall be provided facing outwards at each end of the locomotive. The horns shall be of sufficient size and power to be distinctly audible at a distance of 1 km from the locomotive. The two horns shall have different tones but shall be in harmony with each other when blown together. Push buttons placed next to each other shall be provided for the operation of either one or both the horns at any time by the driver or his assistant.

3.12 Painting and Marking:

The supplier shall submit painting scheme of locomotive indicating paint specification for approval of RDSO.

3.13 Driving Cabs:

3.13.1 A cab shall be provided at each end with provision for adequate forward visibility. The cab shall be adequately insulated against noise, vibration and heat and ingress of water and dust. The two driving cabs of the locomotive shall be adequately reinforced and connected with the main under frame at the cab ends.

The cab shall be ergonomically designed for convenience and to minimize fatigue of the driver. Air heating and ventilation arrangement shall be provided in the cab space. In addition, two nos. of crew fans should also be provided for the driver and assistant driver.

All window and door glasses shall be of shatterproof type laminated glass with sun control film, set in sun and heat resisting synthetic rubber sections. Windscreen wipers shall be provided on the look out windows with foolproof drive arrangement and emergency manual control.

3.13.2 In the layout of the equipment in the driving cab, special consideration shall be given to ergonomics. The driving position will be on the left side of the driving cab. The brake handle shall be located on the left hand side of the driver in the running direction. A second seat shall be provided for the Assistant Driver.

3.13.3 Access to the cab shall be from either side of the cab by means of doors opening inwards. The fixed front glass panel of the cab windscreen and on the doors and side windows of the cab and the fixed glass panels of the equipment compartment shall be of shatter proof laminated duplex glass.

3.13.4 Hinged grill for prevention of damage to the front glass panel of the windscreen shall be provided.

3.13.5 In addition to above, each driver's cab shall be provided with the following:-

i) Two cabinets in the rear and locker for toolbox.
ii) One fire extinguisher in addition to one in the equipment compartment.
iii) One portable hand lamp with electric cable.
iv) Vigilance Control Device of approved design.
v) Space / Room for installation of wireless set.

3.13.6 The equipment compartment / machine room between the two driving cabs shall be designed to ensure maximum accessibility for repair and maintenance of equipment. The equipments in the equipment compartment shall be protected by means of expanded metal doors or panels. Glazed panels shall be provided for fittings, which require frequent visual inspection. Space provided in the corridors shall permit unrestricted movement of driving crew and maintenance staff. Modular construction shall be adopted and equipments shall be provided in compact unit so that they can be easily taken out for replacement, maintenance attention, etc., without disturbing the adjoining equipments. Detachable roof panels shall be provided in the roof for permitting removal of equipments from inside the locomotive. The joints of the roof panels shall be water tight.

CHAPTER 5

INSPECTION, TESTS AND TRIALS

3.1 The locomotive shall be tested generally in accordance with the IEC: 61133. Representatives of Indian Railways shall carry out the inspection of the locomotives. The individual equipment and system/sub-systems as may be necessary shall be type and routine tested in accordance with the relevant standards/specification/publications/details given elsewhere in this specification, which, if required, may be modified to suit local conditions. Type test of electrical and mechanical equipment shall be carried out by the manufacturer at his own responsibility and cost and in the presence of and to the satisfaction of representatives of RDSO. Such tests may include laboratory and field testing for validating design of major mechanical components, like under frame, bogie, suspension systems etc.

3.2 Wherever the relevant standard test procedures do not adequately cover the requirements of arduous environmental conditions prevailing in India, RDSO might lay down special tests apart from those specified that will be required to be conducted at manufacturers works. These may include accelerated ageing tests and endurance test.

3.3 The supplier will formulate and submit a type test protocol / plan for approval of RDSO before undertaking manufacture. It shall, however, be open for RDSO to waive some of tests in case of equipment and sub-assemblies, where the manufacturer can establish to the satisfaction of RDSO that such tests have already been carried out earlier and where equipment has been proved in prolonged service.

3.4 The locomotive shall be subjected to the following tests after receipt in India mainly to satisfy Indian Railways regarding operational performance, capability and safety:-

(i) Oscillation tests to prove the stability & riding performance of the locomotive up to the maximum test speed shall be under taken. These vehicle stability and riding parameters with new and condemning wheel profile should be within the Criteria Limits as per the Latest Revision of Standing Criteria Committee Report of Indian Railways.

(ii) Dynamometer car tests to ascertain starting and rolling resistance of the locomotive and to prove 'tractive effort-speed' characteristics and 'dynamic braking effort-speed' characteristics of the locomotive.

(iii) Adhesion tests to prove the adhesion capability of the locomotive.

(iv) Load haulage tests on different sections with different gradients at different speeds to prove the hauling performance of the locomotive as indicated in the specification.

(v) Emergency braking distance trials to prove the braking capability of the locomotive.

(vi) Tests for checking current collection / pantograph performance of the locomotive.

(vii) Tests to determine the levels of interference with the traction power supply and signal and telecommunication equipments and facilities to prove that these are within acceptable limits.

(viii) Any other tests that may be found necessary.

3.5 The locomotive shall also be evaluated during operation under actual load conditions. These shall be termed as "Service Trials". These trials are intended to prove not only reliability of the operational performance under different conditions of track, load operating conditions, etc. but also to enable practical evaluation of the maintainability, accessibility of

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components, reliability in service and such other aspects which have been envisaged in this specification.

3.6 Modifications found necessary as a result of the tests/trials shall be incorporated by the supplier at his own cost in the locomotives in a manner approved by the purchaser. Drawings incorporating the modifications found necessary, as a result of tests and trials, shall be submitted to RDSO for final approval.

3.7 The components of major equipment like Converter / Inverter shall not be subjected to type tests but their test certificates shall be submitted to RDSO by the contractor.

3.8 Along with the mandatory tests as described in the recent relevant IECs, any other tests mentioned as optional tests, shall also be carried out. Details shall be worked out during design.

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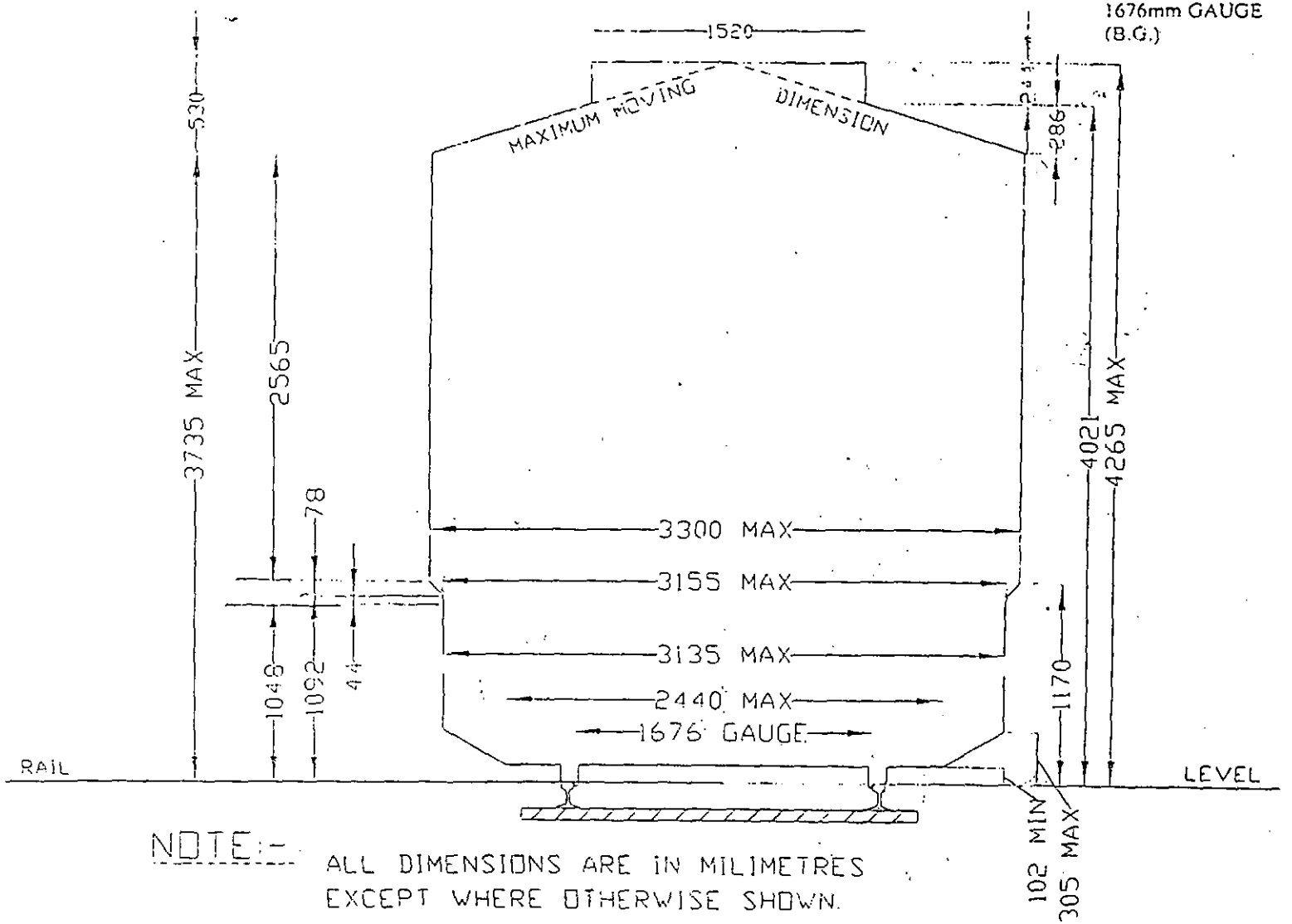
MAXIMUM MOVING DIMENSIONS OF THE PROFILE PROPOSED FOR REVISED SCHEDULE OF DIMENSIONS.

DIAGRAM No.1D
1676mm GAUGE
(B.G.)



NOTE:- ALL DIMENSIONS ARE IN MILIMETRES EXCEPT WHERE OTHERWISE SHOWN.

STANDARD DIMENSIONS IN STATIONS
TO SUIT 25 KV.A.C. TRACTION SCHEDULE-I-CHAPTER-II

MAX. HEIGHT FOR CONTINUOUS

DIAGRAM NO. 2
1676 mm GAUGE
1971

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