सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

TECHNICAL SPECIFICATION

FOR

DESIGN, DEVELOPMENT, SUPPLY AND COMMISSIONING

OF

IGBT BASED 3-PHASE DRIVE PROPULSION EQUIPMENT

ON

WAG9/WAG9H/WAP7/WAP5 ELECTRIC LOCOMOTIVES

Specification No. RDSO/2008/EL/SPEC/0071, Rev.'6'

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MANAK NAGAR, LUCKNOW – 226011

Prepared by	Checked by	Issued by
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Details of Revisions				
S.N.	Date of Revision	Page No.	Revision	Reasons for Revision
1.	01.01.09	7, 18, 23 and 29	'1'	Changes made in Chapter 1: clause 7.6; Chapter 4: clauses 1.6 and 3.0(B). Chapter 4: clause 4.12 deleted, clause 4.13 & clause 4.14 renumbered.
2.	07.09.11	6 to 11, 14, 19, 22, 23, 24 27, 28 and 30	'2'	Chapter 1 : clause 4.0, 5.2 and 8.0 deleted, clauses 6.1 & 7.6 modified and clauses 5.0 to 12.0 renumbered; Chapter 3: clause 1.0 modified; Chapter 4 : clause 1.7 modified, clause 2.2 © and 2.10 added, clauses 2.10 to 2.13 renumbered and clause 2.13, 3.8, 3.13.1(a), 4.6 & 4.11 modified.
3.	Dec'12	5, 7, 8, 13,19, 20, 23, 30, 31, 43	'3'	Clauses renumbered. Clause 1.3(12), clause 1.6.5 deleted, clause 1.6.6 to 1.6.9 renumbered, clause 3.1, clause 4.1.7(v) modified, clause 4.5.5 and 4.1.20 added clause 4.17, clause 4.3.2, clause 4.4.11 and clause 4.4.15 modified. Annexure-F added.
4	May'14	6, 7, 9, 11, 12, 13, 20, 21, 22, 23,24, 25, 26, 27, 28, 30, 31, 33, 35, 38, 40, 42 & 44	'4'	New clause 1.5.5, 1.7.7, 4.1.21, 4.2.15, & 4.3.5.5 added, new para (f) added in clause 4.3.4 (input), Clause 1.5.1, 2.1, 2.2, 2.4.1, 2.5.1, 3.1, 4.1.19, 4.2.8, 4.2.10, 4.2.13, 4.2.14, 4.3.3, 4.3.4, 4.3.5.4, 4.3.8, 4.3.10.1 4.4.5, 4.4.8, 4.4.12, 4.7, 5.2, 5.4, Annexure-B, Annexure-C, Annexure-D & clause 1.3 (a) of Annexure-F revised.
5	June-16	7,19,20,22,23,2	'5'	New clauses 1.5.6, 1.5.7, 1.6.9, 4.2.11, 4.2.17,4.2.18,4.2.19,4.3.13.8 & 4.3.13.9 added Clauses: 1.6.5, 4.1.7(vii), 4.1.11, 4.2.2(c), 4.2.8, 4.2.10, 4.2.13, 4.2.14 & 4.2.15, 4.2.16, 4.2.17, 4.3.6.1, 4.3.10, & 4.3.10.3 revised. Clause 4.2.11, 4.2.12, 4.2.13, 4.2.14 & 4.1.15 renumber as 4.2.12, 4.2.13, 4.2.14, 4.2.15 & 4.2.16, 4.2.17 due to addition of new clause Clause: 1.5.3.7, 1.5.5 & 4.4.14(c) deleted Locomotive WAP5 has been included and added in all relevant clauses of spec Parameter of WAP5 added in cl: 2.1 Performance of WAP5 added in cl: 3.1 TE/BE curve added in cl: 3.1.1

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CHAPTER 1

GENERAL DESCRIPTION AND SUPPLIER'S RESPONSIBILITIES

1.1 Introduction

1.1.1 Indian Railways (IR) is currently manufacturing electric locomotives employing 3-phase drive IGBT propulsion equipments for fitment on WAG9/WAG9H/WAP7/WAP5 locomotives.

1.1.2 These propulsion equipments shall be provided by the Supplier in WAG9/WAG9H/WAP7/WAP5 locomotives fitted with brake system and other equipment at Production Units.

1.1.3 This specification defines the technical requirements of design, development, manufacture, testing, supply, delivery and commissioning of IGBT based 3-phase propulsion equipments comprising of traction converter, auxiliary converter, vehicle control unit (VCU), Driver Display Unit (DDU) and their interconnections including documentation etc. for assembly on WAG9/WAG9H/WAP7/WAP5 locomotives of Indian Railways. The performance requirements, environmental & service conditions, technical requirements and inspection, tests and trials are specified in the following chapters of this specification. The existing three phase Traction Motors 6FRA 6068/6FXA 7059 and the existing Transformer LOT 6500/LOT 7500/LOT 7775 shall be retained for WAG9/WAG9H/WAP7/WAP5 locomotives. Two series resonant chokes available in the existing transformer also are to be used. The details of Transformers and Traction Motors are given in Annexure B. Use of the existing choke has to be mandatory since transformer is to be retained.

1.1.4 The design and manufacturing of equipment shall be based on sound, proven and reliable engineering practices. The equipment used in different sub-systems shall be of proven technology and design.

1.1.5 The specification envisages for design, development, manufacture, testing, supply, delivery and commissioning of IGBT based 3-phase propulsion system consisting of traction converter, auxiliary converter, control electronics (Vehicle control unit), Driver Display Unit (DDU) and other accessories as mentioned in scope of supply.

1.1.6 The Supplier has responsibility of engineering adaptation of the equipment and system integration of the locomotives.

1.1.7 The existing equipment layout in the machine room shall be studied by the Supplier. Traction Converter, Auxiliary Converter, Control Electronics (Vehicle Control Unit) and Driver Display Unit (DDU) shall fit in existing locations of these equipments. Present mechanical drawings can be obtained from CLW/Chittaranjan.

1.2. Abbreviations and Definitions

'IR' means Indian Railways or it's nominated agency

'RDSO' means Research Designs & Standards Organisation

'Engineer' means IR, Ministry of Railways

'CLW' means Chittaranjan Locomotive Works

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

'Sub Supplier' means any person, firm or company from whom the Supplier 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

'OEM' means Original Equipment Manufacturer

'BG' means 1676 mm Broad Gauge used in IR

'IS' means Indian Standard

'IRS' means Indian Railways Standard

'IEC' means International Electro-technical Commission

'IEEE' means Institution of Electrical and Electronics Engineers

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

'ISO' means International Standards Organisation

'MDBF' means Mean Distance between Failures

1.3 References to Various Standards:

This Specification is based on the following Normative References and standards:

1.	IEC-61287-1	Railway applications - Power Converters mounted on board rolling stock – Part1: Characteristics and test methods.
2.	IEC-60571	Railway applications – Electronic equipment used on rolling stock.
3.	IEC-60349-2	Electronic converter fed alternating current motors
4.	IEC – 60505	Evaluation and qualification of electrical insulation systems
5.	IEC – 61375-1	Electronic Railway Equipment-Train Communication Network (TCN) – Part 1: General architecture.
6.	EN 50121-3-2	Railway applications – Electromagnetic compatibility – Part 3-2 : Rolling stock – Apparatus.
7.	EN 50121-2	Railway applications – Electromagnetic compatibility – Part 2 : Emission of the whole railway system to the outside world.
8.	IS 3231	Relays and Contactors
9.	IEC 60228, IS 10810	Conductors and Insulated Cables
10.	IEC 61373	Railway applications – Rolling stock equipment – shock and vibration tests
11.	IEC 61377	Railway applications – Rolling stock – Combined test method for traction systems
12.	IEC 60077–1	Railway applications – Electric equipment for rolling stock – Part 1: General service conditions and general rules

13.	IEC 60077–2	Railway applications – Electric equipment for rolling stock – Electro technical components - stock – Part 2: general rules
14.	IEC 61131	Railway application – Rolling Stock – Testing of rolling stock on completion of construction and before entry into service
15.	EN 50153	Railway application – Rolling Stock – Protective provisions relating to electrical hazards
16.	EN 60529	Degree of protection provided by enclosures (IP code)
17.	IEC 62278:2002	Railway applications - Specification and demonstration of reliability, availability, maintainability and safety (RAMS)
18.	IEC-62313	Railway applications - Power supply and rolling stock - Technical criteria for the coordination between power supply (substation) and rolling stock.
19.	IEC 62497-1	Railway applications – Insulation coordination – Part 1: Basic requirements – Clearances and creepage distance for all electrical and electronic equipment.
20.	IEC 61000-4-5	Electromagnetic compatibility (EMC)- Part 4-5: Testing and measurement techniques – Surge immunity test.
21.	IEC 61000-4-4	Electromagnetic Compatibility (EMC) – Part 4: Testing and measurement techniques – section 4: Electrical Fast Transient/burst immunity test.
22.	IEC 62236-3-2	Railway applications - Electromagnetic Compatibility – Part 3-2: Railway Stock-Apparatus.
23.	IS2102 (Part1)	Tolerances for linear and angular dimension without individual tolerance indications.
24.	ISO 2768-1	Tolerances for linear and angular dimension without individual tolerance indications.
25.	IEC 61881-2010	Rolling stock equipment – Capacitors for power electronics.
26.	IEC 60310-2016	Railway applications - Traction transformers and inductors on board rolling stock.
27.	EN 50238	Design aspect for controlling emission and immunity test methodology and test plan
28.	IEC 62498	Various classes of atmospheric temperature conditions for operation.
29.	EN 50467	Railway applications – Rolling stock – Electrical connectors, requirements and test method
30.	EN 50128/ IEC 62279	Railway applications - Communication, signaling and processing systems- software for railway control and protection systems.
31.	GM/RT 2472, EN 62625 :	Requirements for data recorders on train.

32.	CLC/TS 50701	Railway applications- Cyber security
33.	BS EN 16186	Railway applications- Driver's cab

1.4 Deleted.

1.5 Scope of supply

1.5.1 The propulsion system to be supplied consists of following equipments:

- IGBT based Traction Converter / Inverter
- IGBT based Auxiliary Converter / Inverter
- Coolant with pump and MPCB including sensors & transducers.
- Control, communication and protection system, including sensors & transducers
- Driver Display Unit (DDU) and its interfacing with VCU in each cab along with C panel.
- Interface with other equipment not in the scope of the supply of this specification such as brake system, speedometer, RTIS, KAVACH/TPWS, RMS etc. GPS clock to be used for timestamp.
- Apparatus / interlocking arrangement for ensuring safety of the operating and maintenance personnel.
- SB to VCU cable with connectors and loom.
- Interconnection details like MVB, connector, Cu braid, terminal link, ESD.
- Master controller as per CLW specification No. CLW/ES/3/0031 Alt. 1 or latest.
- Traction motor speed sensors.
- Source Code deposition and life time support and compiler of software of Traction Converter, Auxiliary Converter and Vehicle Control Unit (VCU)

  OR

  Supplier shall provide life time support for software modification/upgradation as required by I.R. free of cost. An undertaking to this effect shall be furnished at the time of submission of tender document.
- Bottom mounting and top fixing arrangement/brackets along with all necessary accessories/hardware for mounting of Propulsion system in loco.
- Other equipments/components mentioned in this specification and standards.

1.5.2 Commissioning and testing of above equipments in WAG9/WAG9H/WAP7/WAP5 locomotives.

1.5.3 The scope of supply shall also extend to the following:

1.5.3.1 Supplier shall provide document in line with ToT ABB doc no. 3EHN420456/ 3EHP510054/3EHW500453/3EHP551009/3EHP5510010. These shall be used for approval of design (see clause 1.7 of this specification).

1.5.3.2 Support documents associated with the operation and maintenance of the equipments in hard and soft copies. The full documentation shall include Maintenance Manuals, Operation Manuals, Detailed Troubleshooting Directory stating all the probable faults/information messages displayed in diagnostics along with cause, effect and remedial action concerned with fault, Training Manuals, QA documentation, set of maintenance spare/cards/modules to be kept in shed per 10 loco basis for warranty/AMC obligation to reduce downtime etc.

1.5.3.3 Complete know-how for assembly, testing and commissioning of the equipment on the locomotive shall be transferred to IR at concerned Production Unit. The engineering know how shall include assembly / testing / commissioning process details, requisite drawings, training of staff and maintenance instructions. These are required in order to enable series production of such IGBT based WAG9/WAG9H/WAP7/WAP5 locomotives at production units.

1.5.3.4 One set of special tools, jigs & fixtures, special test equipment etc. for assembly, testing, commissioning, maintenance and operation of propulsion system, along with documentation, specification and purchase information thereof with the prototype unit and further on need basis of Production Units/Zonal Railways.

1.5.3.5 Suitable software tool and laptops (one laptop per 10 loco sets propulsion system or part thereof) to download/fetch any type of data for analysis as per clause 4.4.8 and 4.4.9 of this specification. Laptop shall be of industrial grade with configuration of processor i5 or above current generation or equivalent processor with minimum 8GB RAM & 512 GB SSD. Software tool for downloading VCU, SR, BUR data to be provided along with feature of online monitoring of various parameters like TM current, BUR DC link voltage etc. to be provided. Prior approval of software tool is to be obtained at design stage.

1.5.3.6 Application software package required interacting with the Vehicle Electronics and for changes in locomotive software operating parameters (like preset values, limits, characteristics etc. and behaviour of the locomotive in general) and other functions as per clause 4.4.10 of this specification.

1.5.4 The existing HB1/HB2, SB1/SB2 and Filter Cubicle shall be retained. Necessary interface of propulsion equipments with these cubicles have to be provided by the Supplier. Necessary cable and connector for SR to Traction Motor, VCU to SB and VCU to DDU to be provided by the supplier.

1.5.5 Physical Medium i.e. ESD/EMD/OFG for Multi-Functional Vehicle Bus (MVB) as IEC 61375, Terminal Bracket, Bus Bar Link and Cu Braid required for connection between Main Transformer and Traction Converter, Auxiliary Converter, Harmonic Filter (FB), earth return path, interfacing connectors, cables and cable looms required for connection from VCU1/2 to SB 1/2 Panel.

1.5.6 One Lifting jig with safety certificate per 40 loco sets of propulsion system or part there of shall be supplied for traction converter and Auxiliary Converter. One no. pump for filling coolant in traction converter shall be supplied per 50 loco set or part thereof. Quantity of coolant to be supplied will be 200 litres.

1.5.7 02 nos. DIN rail mountable MPCB each of 6.3-10A or suitable rating with different setting along with 02 NO auxiliary contacts compatible with coolant pump, per loco set of propulsion system. Prior approval for the MPCB will be taken from IR.

1.5.8 Existing standardized base frame/plate for mounting of converters. Approved drawing for the same shall be made available by IR.

1.6 Supplier's Responsibilities

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

1.6.1 The Supplier is expected to study the existing design, drawing and layout of WAG9/WAG9H/WAP7/WAP5 locomotives. The drawings can be obtained from Chittaranjan Locomotive Works, Chittaranjan. Wherever the supplied equipment has to mechanically interface with the existing equipment, requisite matching shall be ensured.

1.6.2 The Supplier shall arrange required instrumentation for mechanical and electrical tests to be conducted in field as per standards stipulated in this Specification and carry out detailed tests and field trials. The Supplier shall ensure availability of tools, testing equipment, measuring instruments & spare parts in adequate quantity for tests and field trials.

1.6.3 The Supplier shall be entirely responsible for the supply and commissioning of propulsion system in accordance with the requirements of this specification.

1.6.4 The supply against this contract shall be designed in accordance with the specification and the Supplier's technical proposal for the satisfactory performance of the stock in service notwithstanding any approval which the Engineer or the Inspecting officer may have given:

i) to the detailed drawings prepared by the Suppliers,

ii) of a Sub Supplier for material,

iii) of other parts of the work,

iv) of the tests carried out by the Supplier, Engineer or Inspection Officer.

1.6.5 After successful commissioning in one of the WAG9/WAG9H/WAP7/WAP5 locomotive, first set of equipment shall be subjected to tests as per clause 5.1 of this specification. There after the equipments shall be subjected to a defect free Service Trials for a minimum 50,000 Kms (fifty thousand kilometres) as per clause 5.7 of this specification. During field trial period, if any failure related to software/hardware recorded, the field trial period shall suitably be extended to the defect free field service of further 50,000 Kms. The further supply of the propulsion system shall start after successful completion of service trials. 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 shall be taken by the Supplier 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 Supplier shall not proceed with any modifications / improvements unless approved by IR. Such modifications / improvements shall be carried out in all locomotives and shall be evaluated for their validity for a further period of time as may be agreed mutually in each case.

1.6.6 For the equipment supplied / arranged by the Supplier, modifications mutually agreed to comply with the specification 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 test and trial shall be submitted to IR for approval before carrying out the modifications.

1.6.7 The Supplier 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.

1.6.8 **Training**: The Supplier shall arrange for the training of Production Units, RDSO and the maintenance & operating personnel of IR of 5 man months at supplier's premises, where each man month shall be of 25 working man days. The cost of training shall be included in the offer. The details of the training shall be worked out during contract finalisation stage/design approval stage.

1.6.9 Necessary simulator setup to be kept at firm's/manufacturer premises for real time simulation and validation of software/hardware of propulsion equipment to ensure quick redressal of field problems/software upgradation.

1.7 APPROVAL OF DESIGN

1.7.1 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.

1.7.2 The entire design shall be supplied by the Supplier with required technical data and calculations to IR for approval. The manufacturing shall commence after and as per the approval of design by IR. Three sets of IR approved design are to be supplied by the Supplier. The actual distribution shall be finalised during design stage.

1.7.3 Deleted.

1.7.4 The Supplier shall submit all necessary data, designs, calculations, graphs, drawings and specifications referred in their drawings or design documents in English language as required by IR for examination and shall provide explanation and clarification of the documents for which approval is sought. For the purpose, the Supplier shall depute its technical experts to IR for design discussions and finalisation. After the final design is approved, the Supplier 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.

1.7.5 Supplier 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 etc. The aspects covered above are not exhaustive and the Supplier shall commit to supply / furnish complete technical details with respect to their system and equipment design and to the satisfaction of IR for design approval. Further, calculation of the semiconductor devices like IGBTs, Thyristors, Diodes at worst-case operating conditions shall be submitted ensuring capability of the selected item with proper safety margin as mentioned in clause – 4.1.14 of this specification and standards. Also, calculation for proper cooling circuit adopted shall be submitted for traction and auxiliary converter considering the Climatic and Environmental Conditions given in clause – 2.3 of this specification and standards. All documentation concerned with the equipment shall also be shared with Zonal Railways in addition to IR including BoM.

1.7.6 Supplier shall enclose details of their system design, weight particulars and its disposition covering all items, viz, Converter/Inverter, Auxiliary Converter, control system etc., basic software specification, electronics, communication protocols, display systems and any other aspect / equipment which is within the scope of supply of the Supplier. The Supplier shall also submit in their offer the simulated values of the maximum interference currents in the power supply. Supplier shall refer to Annexure-A while enclosing the details.

1.7.7 A documentation giving description of design aspect for controlling emission and immunity, test methodology and test plan as per EN 50238 & EN 50121 standards shall be submitted to IR for approval.

1.7.8 Deviations proposed by the Supplier in the interest of reliability and better performance shall be examined by IR in close consultation and association with the manufacturer so as to arrive at the final locomotive design.

1.7.9 The Supplier 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.

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

1.7.11 Approval of design means the approval of general design features. Notwithstanding approval from IR, the Supplier shall be wholly and completely responsible for the satisfactory performance of the equipment.

1.7.12 The Supplier 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 Supplier and Purchaser.

1.7.13 For the purpose of technical decisions on improvements/modifications etc. on equipment, the final authority from the Purchaser's side shall be IR.

1.7.14 The 3D models of all the cubicles of propulsion system, compatible to NX platform shall be submitted.

1.8 STANDARD SPECIFICATIONS

Latest version of International Electro-Technical Commission (IEC) publications, European Standards (EN) and Indian Standards (IS) as far as applicable and relevant to the various equipment, systems and sub-systems shall be considered. The standards applicable for equipment as well as for materials shall be furnished during design approval stage. In case of any conflict between the requirements of this specification and standards, the stipulations of this specification shall have precedence. In case of contradictions between these standards, the same shall be agreed mutually. Any deviations from these specifications as specified herein and as may be mutually agreed to subsequently between the Supplier and IR shall not reduce reliability or decrease safety margins. Some of the relevant standards are given in clause 1.3 of this specification.

1.9 DOCUMENTATION

1.9.1 The Supplier shall furnish as made drawings and tracings, manual of instructions for operation and maintenance of the equipments, troubleshooting instructions and such other technical information as may be required for the maintenance and operation of the equipments in India. A preliminary version shall be supplied along with the despatch of the first equipments from the Supplier's works. Final documentation shall be provided incorporating experience gained in final manufacturing phase and the first period of trials within 6 months after completion of these trials.

1.9.2 Operation Manual

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

1.9.3 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 troubleshooting tools and all other information necessary to set up repair and servicing programme. Those shall be accompanied by suitable illustrations & diagram. It shall include inspection / overhaul procedure and periodicity of various inspection / overhaul schedules in detail, including the tools, special tools / plants, and facilities required. An illustrated parts catalogue with sufficient information to identify and requisition any part shall be included.

1.9.4 Clarification and amendments to the document, particularly operations and maintenance manual, as necessary during the defect liability period shall be supplied by the Supplier. Updates shall be provided for the original and all copies supplied. Maintenance and trouble-shooting manuals shall be updated every 3 years including all the reliability action plan implemented, control circuit changes done, revised trouble-shooting instructions etc. that were made in the 3-year period after previous revision and same shall be supplied to all sheds of IR in both soft copy and hard copy.

1.9.5 The operations & maintenance manuals shall be supplied @ 1 set (hard copies) per equipment. All the document shall be supplied in electronic form along with software and hardware tools to read and print them. The manual shall be in bilingual, generally in A4 size and shall be bound with wear resistant covers.

1.10 INFRINGEMENT OF PATENT RIGHTS

Indian Railway shall not be responsible for infringement of patent rights arising due to similarity in design, manufacturing process, components used in design, development and manufacturing of propulsion system and any other factor which may be a cause such dispute. The responsibility to settle any issue lies with the manufacturer.

1.11 While utmost care has been taken to prepare this specification, any contradiction or typographical errors or any other mistake will be taken care of at the appropriate stage.

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CHAPTER - 2

OPERATING & SERVICE CONDITIONS AND DESIGN CONSTRAINTS

2.1 Leading parameters of Locomotive:

Parameter	WAG9 locomotive	WAG9H locomotive	WAP7 locomotive	WAP5 locomotive
Axle load	20.5 tonnes ± 2%	22.0 tonnes ± 2%	20.5 tonnes ± 2%	19.5 tonnes ± 2%
No. of axles	6	6	6	4
Weight	123 tonnes ± 1%	132 tonnes ± 1%	123 tonnes ± 1%	78 tonnes ± 1%
Max. design speed	100 kmph	100 kmph	140 kmph	160 kmph
Test speed	110 kmph	110 kmph	155 kmph	180 kmph

2.2 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	31 kV
Occasional minimum voltage	16.5 kV
Variation in supply frequency	± 8% (46 to 54 Hz)

2.3 Climatic and Environmental Conditions:

➢ Atmospheric temperature	The locomotive shall operate in T6 class of atmospheric temperature conditions as specified in IEC62498-1. Maximum temperature: 55°C Maximum touch temperature of metallic surface under the Sun : 85°C and in shade : 60°C max. Temp. inside working locomotive may reach 65°C. Minimum temperature: -20°C (Also snow fall in certain areas during winter season) Atmospheric temperature shall be -10 to +50 degree Celsius for guaranteed performance.
➢ Humidity	100% saturation during rainy season.
➢ Altitude	Altitude: 1776 m above mean sea level (1041 m for guaranteed performance)
➢ Rain fall	Very heavy in certain areas.
➢ Snow & Hail	705 mm

➢ Ice load	5% loading was adopted for OHE design
➢ 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/m^3. 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 shall be mounted. Necessary precaution shall be taken in this regard.

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

2.4 Interferences:

2.4.1 The electric and electronic apparatus used in propulsion system shall comply emission and immunity aspects of EMC to CENELEC standard EN 50238 and EN-50121. The internal EMC shall cover a combination of earthing, shielding and isolation of interference sources so that conducted and radiated noises are properly segregated or suppressed and no other equipment is affected due to operation of propulsion equipments.

2.4.2 The tracks over which the offered locomotive propulsion system shall work shall 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., shall also be employed. On the communication network, control circuits, teleprinter circuits, as well as VHF/UHF and micro-wave circuits are employed.

2.4.3 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 shall 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 (100 Hz)	8.5 A
1400 Hz to 5000 Hz	400 mA
More than 5000 Hz up to 50000 Hz	270 mA

2.5 Weight and layout particulars

2.5.1 Weights of the major equipment of GTO based locos are as follows:

- Traction Converter / Inverter (2 nos.) : 3330 kg each (however weight of IGBT based traction converter shall be around 2500 kg)
- Auxiliary Converter (3 nos. in 2 boxes) : 608 kg (box1) + 1130 kg (box2)
- Control cubicle SB1 & SB2 incl. control electronics : 160 kg + 170 kg = 330 kg

Weights of equipment to be fitted in the locomotive have to be considered to make sure the final locomotive weight remains as per stipulation in this specification. **Production Units may determine the weight of propulsion equipment as per requirement of different type of locomotives.**

2.6 Codal life of individual equipment and complete propulsion system shall be submitted by OEM during design approval stage. Life cycle cost of spares for major equipment and sub-equipment shall be specified by OEM during design approval as well as during supply of complete propulsion system.

Necessary spares of the propulsion equipments shall be supplied by OEM to IR during the extent of codal life period.

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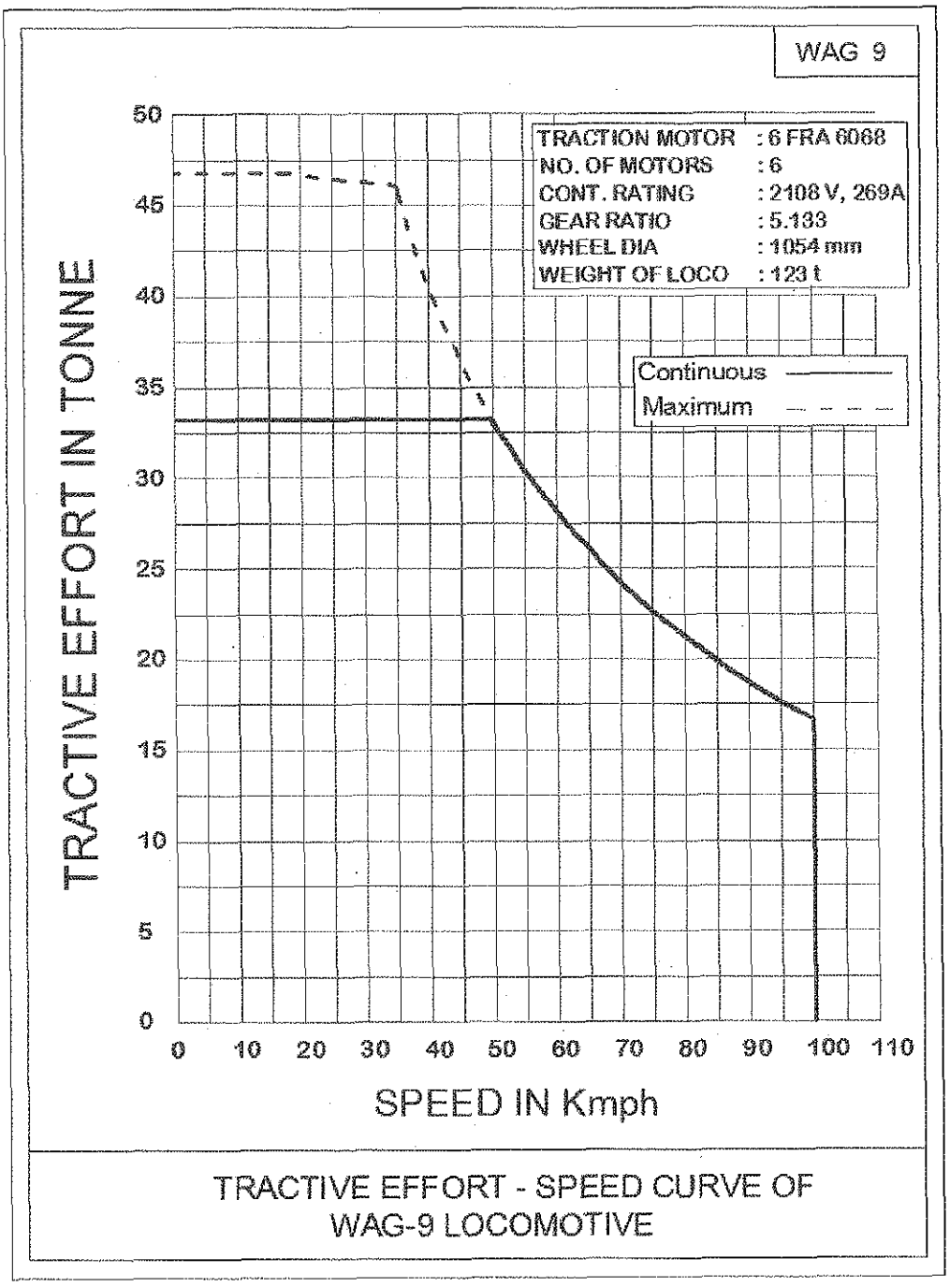
CHAPTER 3

PERFORMANCE REQUIREMENTS

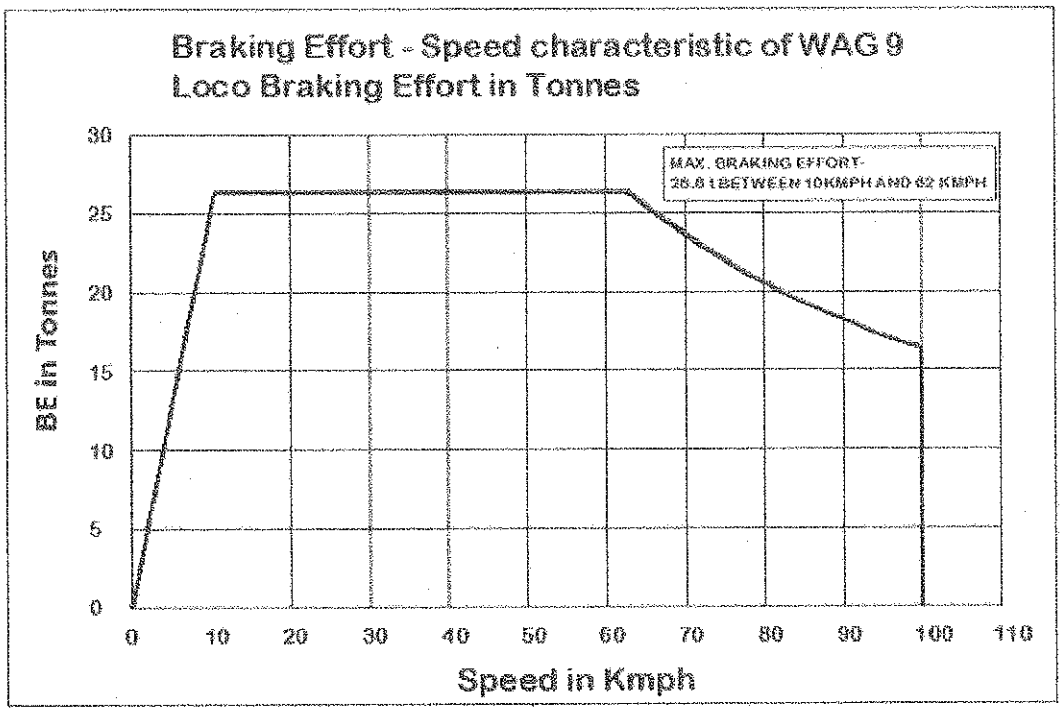
3.1 **Performance:** At 22.5 kV line voltage and half worn wheels, locomotive fitted with the propulsion equipment shall be capable of the following performance under the reference site conditions. Full traction power shall be available in the voltage range of 22.5 kV to 30 kV and normal range of frequency of power supply. Variation of power, if any, up to the specified occasional minimum voltage range shall be linear to voltage reduction but shall not be less than 80% of the full power in the specified occasional minimum voltage range. There shall be no reduction in the maximum tractive effort in the maximum to minimum operative range of OHE voltage and frequency range.

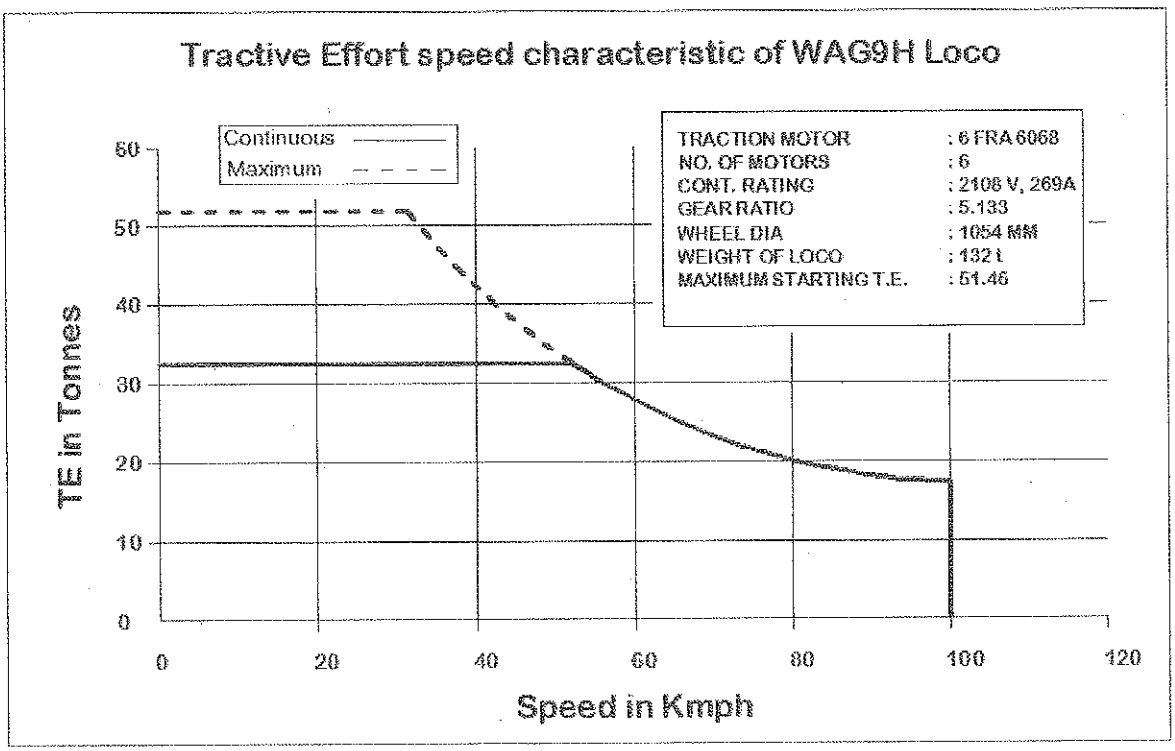
	Parameter	WAG9 locomotive	WAG9H locomotive	WAP7 locomotive	WAP5 locomotive
(i)	Starting tractive effort under dry rail condition	Not less than 460 kN	Not less than 500 kN	Not less than 322.6 kN	Not less than 258 kN
(ii)	Continuous rated TE up to speed	Not more than 50 kmph	Not more than 50 kmph	Not more than 70 kmph	Not more than 50 kmph
(iii)	Max. design speed	*100 kmph*	*100 kmph*	*140 kmph*	*160 kmph*
(iv)	Continuous rated power at rail	Not less than 4500 kW at all speeds from continuous speed to max. design speed	Not less than 4500 kW at all speeds from continuous speed to max. design speed	Not less than 4500 kW at all speeds from continuous speed to max. design speed	Not less than 4500 kW at all speeds from continuous speed to max. design speed
(v)	Regenerative brake	Maximum possible without skidding over full speed range but not less than 260 KN for WAG9/WAG9H loco and Maximum possible without skidding over full speed range but not less than 182 KN for WAP7 loco and Maximum possible without skidding over full speed range but not less than 160 KN for WAP5 loco			

3.1.1 The present characteristics of WAG9, WAG9H, WAP7 and WAP5 locomotive with GTO based propulsion are given below :

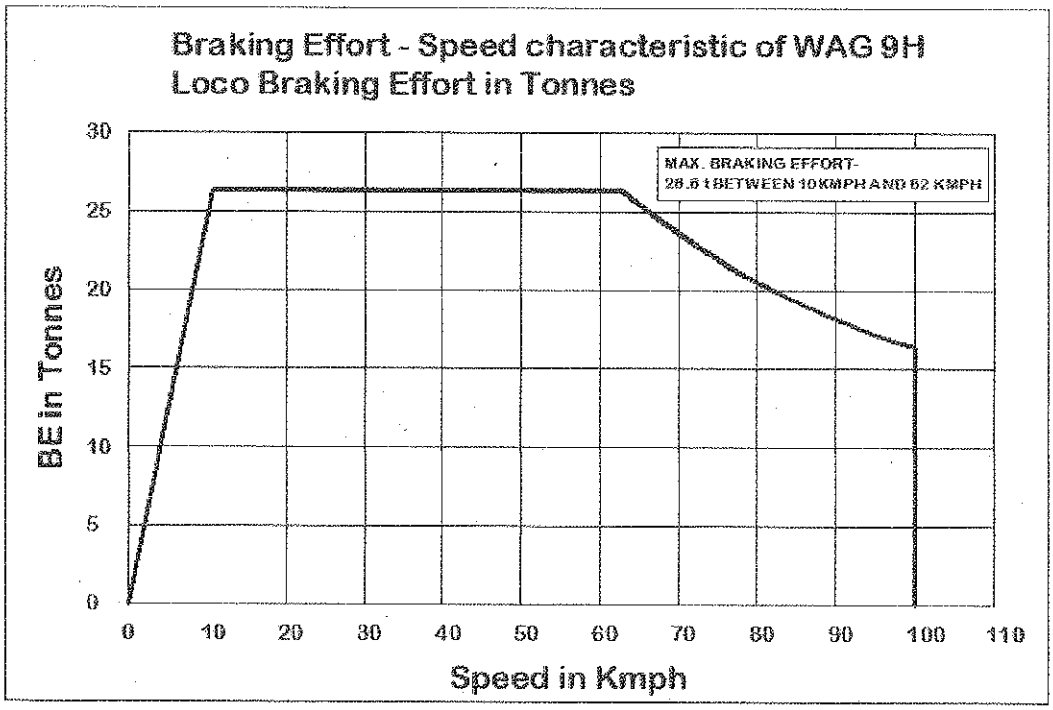


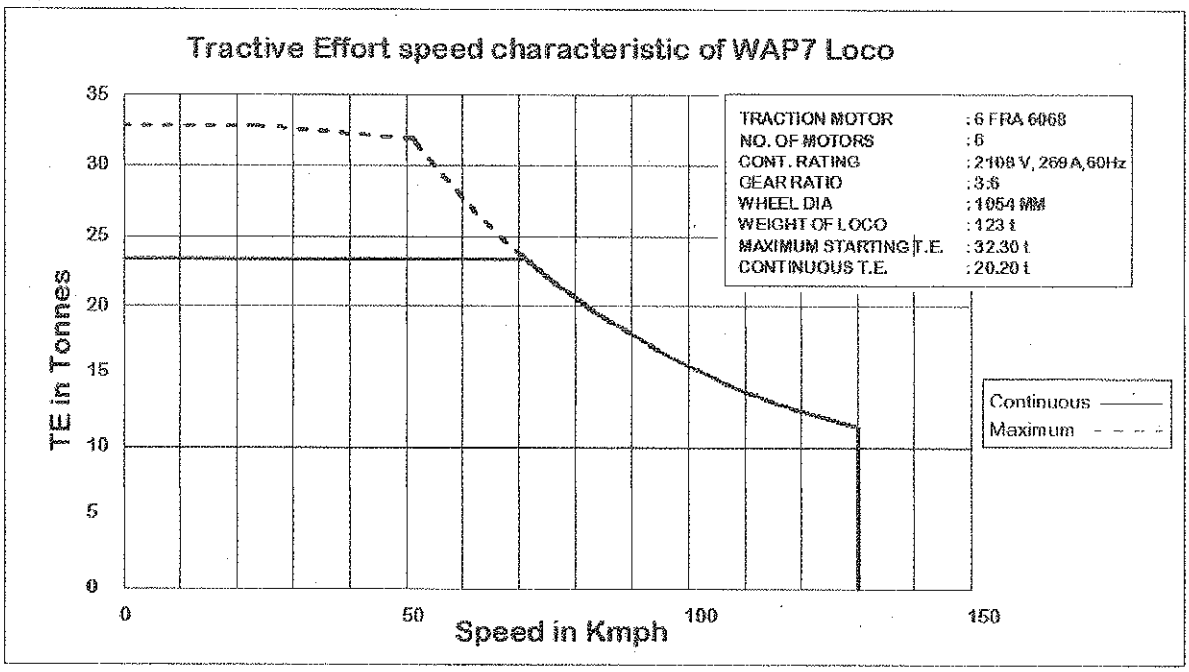
TRACTIVE EFFORT - SPEED CURVE OF WAG-9 LOCOMOTIVE





Prepared by	Checked by	Issued by
SSE/Design/RDSO	DSE/TPS/RDSO	ED/RS/RDSO





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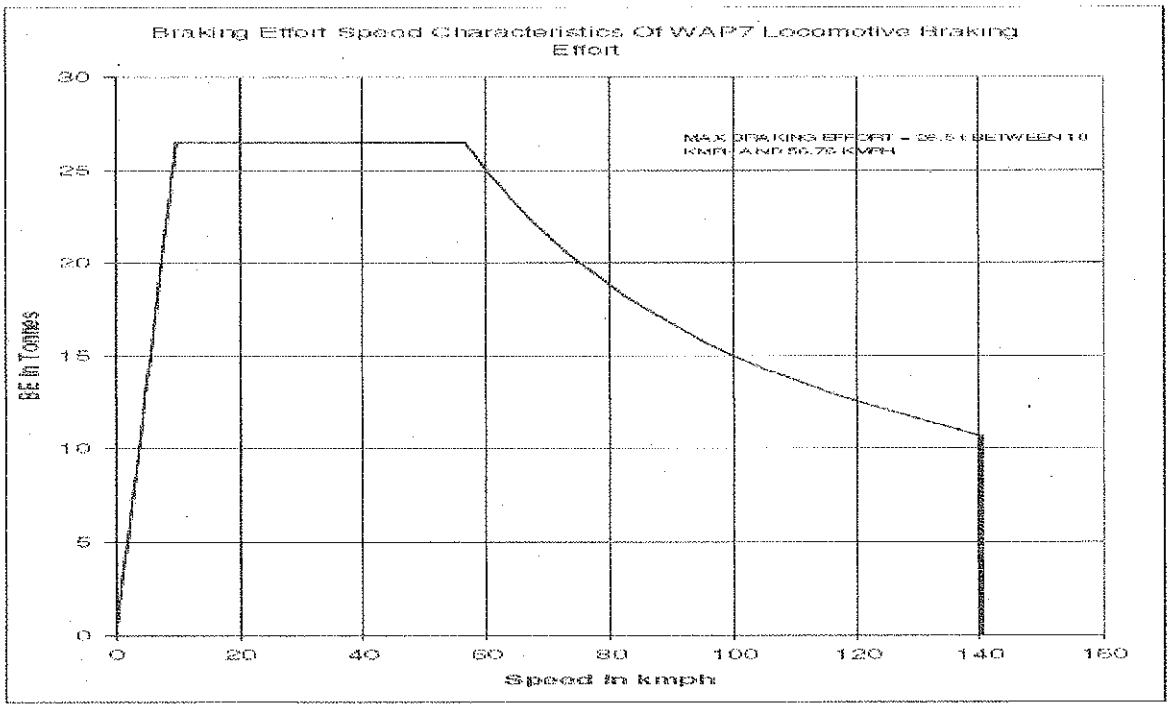

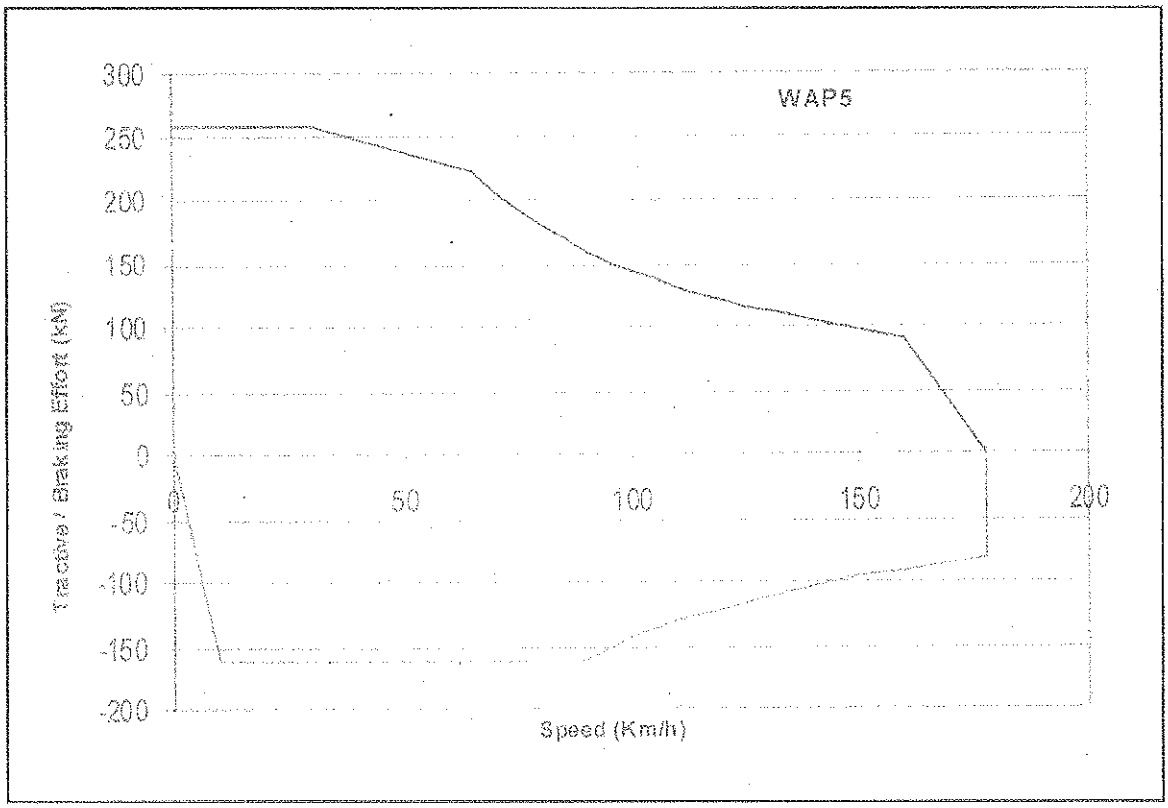

Note: TE/BE Characteristics of WAP5 locomotives given above is for continuous rated power of 4000 KW. Presently, continuous power of WAP5 locomotive has been enhanced to 4500 KW.

Prepared by	Checked by	Issued by
SSE/Design/RDSO	DSE/TPS/RDSO	ED/RS/RDSO

3.1.2 With adoption of IGBT based propulsion system using same transformer, traction motor and gears & pinions, the Tractive Effort / Braking Effort curves WAG9, WAH9H, WAP7 WAP5 locomotive shall match the existing curves.

3.2 Duty Cycle:

WAG9/WAG9H locomotive working in adverse terrain shall be required to negotiate longer periods at lower speeds. The typical duty cycle encountered in operation shall be as given below and loco propulsion system and equipment shall be able to work satisfactorily under such conditions.

Speed (in km/h)	0-10	10-30	30-60	60-80	80-100
% of total running time of locomotive	10 %	15 %	35 %	25 %	15 %

3.3 Adhesion:

The design of the adhesion control shall be optimised for maximum utilisation of adhesion factor and shall be such that it is capable of generating the required starting tractive effort under dry rail conditions. Under dry rail conditions, the Locomotive shall be able to generate tractive effort during start and at low speeds corresponding to meet the requirement as per characteristics given in Para-3.1.1 of this specification and standards. Adhesion of the locomotive should not be reduced by more than 20% of maximum dry rail adhesion during wet & contaminated rail condition. The adhesion control system shall be capable of giving high adhesion through a wheel slip control system through optimal exploitable creep force. The mechanism with necessary formulae and graph for linking adhesion characteristics with the percentage rail wheel creep in dry, wet and contaminated rail wheel conditions at different operating speed shall be submitted at Design Stage. The Supplier shall state the value of maximum starting tractive effort that shall be developed under dry rail conditions and also under all weather conditions, which shall be demonstrated during testing. The achievable running adhesion characteristics shall be made available. The formulae for linking adhesion characteristics with the operating speed shall be indicated. During wet rail condition TE should normally not fall below 80% TE of dry rail. Indication lamp is available in cab (LSP) and it should be activated by the propulsion system indication for the tractive effort control to crew to wheel slip detection.

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CHAPTER 4

TECHNICAL REQUIREMENTS

4.1 GENERAL

4.1.1 The equipment shall be of 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. Features to yield high availability for traffic use, low maintenance requirements, easy maintainability, high reliability in operation and high efficiency shall be incorporated. IGBT propulsion equipment should be designed in such a way that in general removal of loco roof should be avoided for replacement of various sub-components except in case of complete unit replacement.

4.1.2 The system and equipment shall be specially adopted for application to meet the performance requirements under environmental conditions specified in Chapter 2 & 3 of this specification. Adequate margin shall 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.

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

4.1.4 It shall be possible to use the locomotive in multiple unit operation of 02 (two) or more locomotives in one group. The entire control of locomotives shall be achieved from the leading locomotive under multiple locomotive operations. The Locomotive shall be suitable for synchronous control system through wireless signals between Locomotives which may consist of two/more than two Locomotives, distributed in the train formation at the head of the train, in between or at the rear end of train for operation of heavier and longer trains as per CLW specification No. CLW/C-D&D/ES/3/0540, Alt. A or latest. The control and operating signals from the lead Locomotive shall be transmitted to the trailing Locomotives through radio transceiver to allow all the trailing Locomotives to be operated in synchronization with a single driver control from the lead Locomotive. Encryption shall be provided for commands sent from the leading Locomotive and feedback messages from the trail Locomotives for security purposes. The display in the driver's cab shall indicate the status of feedbacks received from the trailing Locomotives. It shall be possible to view the status of important and vital parameters of all the trailing Locomotives from the leading Locomotive in wired/wireless operation, which are considered necessary for safe and trouble free operation, 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 in leading or trailing position. While working in multiple unit (MU) operation, provision shall be given to lower the pantograph of rear loco/locos from leading loco itself. Also switching OFF/ON of the rear loco MCE from leading loco shall be provided. The generation of fault message in case of fault shall be displayed on both loco DDU along with loco number and storage of the fault shall be in the defective loco itself. The propulsion system shall be compatible to work in Multiple/consist with other makes of propulsion system as per agreed Interface Control Document (ICD).

4.1.5 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 per locomotive, to be decided during design stage.

4.1.6 Provision shall be made to enable operation of locomotive under inching control mode at a constant speed settable by the driver in steps of 0.1 Kmph, in the range 0.5 Kmph to 1.5 kmph in yards for a load not greater than 6000 tonnes and on a gradient of 1 in 1000 or flatter. It shall be possible to change from inching control mode to Normal Mode and vice versa by the driver depending upon his requirement. Provision shall also be made to enable operation of locomotive in shunting mode up to 15 kmph in yards for a load not greater than 6000 tonnes and on a gradient of 1 in 1000 or flatter.

4.1.7 Adequate redundancy shall be built in with the design in order to improve reliability and availability. 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 shall be provided preferably with automatic substitution features to avoid locomotive failure or drastic reduction in performance due to such defects. The power supplies to the control circuit shall be hot redundant. The redundancy requirements are given in following paragraph.

No single-point failure of the propulsion system shall cause the complete failure of the locomotives and the number of single point failures which would result in a loss of more than $1/6^{th}$ (one sixth) of the traction power shall be minimised. The Supplier shall identify and advise the Purchaser of any single-point failures that shall cause a loss of power of $1/6^{th}$ (one sixth) or greater of the traction power as part of the design details. Further, the details of redundancy provided in the propulsion equipments shall be submitted as part of the design details.

Complete redundancy of power supply, processor, digital & analogue I/O cards and communication channels needs to be provided.

List of all cases of protective shut down where traction converter or auxiliary converter gets locked permanently without software reset shall be submitted for approval of IR.

In the event of breakdown of any component or basic unit of equipment, it shall be possible to continue to haul the train with the least reduction possible in its services, operating within restricted but permissible conditions. The basic principles and procedures to be followed in the event of a breakdown shall be:

i) Breakdown of drive side converter of traction converter or electrical failure of traction motor: The power of the locomotive shall be reduced only by 1/6 (one sixth). In case of electrical failure of TM like earth fault or inter turn short also the power of locomotive must only be reduced by 1/6th and only TM concerned is to be isolated. Additional provision of TM cut out switch to be provided with switch position, to cut out individual TM by the crew during troubleshooting. It is also required to isolated defective drive converter through DDU by Loco pilot when required (for example Earth fault in motor). Physical separation of module is suggested so that in case of physical damage of one module due to bursting, performance of other must not get affected.

ii) Breakdown of line side converter of traction converter: The power of the locomotive shall be reduced only by 1/4 (one fourth). Physical separation of

module is suggested so that in case of physical damage of one module due to bursting, performance of other must not get affected.

iii) Failure of drive controller unit or power supply of the drive controller unit or gate unit or gate unit power supply of a drive side converter of traction converter: The power of the locomotive shall only be reduced by 1/6 (one sixth).

iv) Failure of Line controller unit or power supply of the Line controller unit or gate unit or gate unit power supply of line side converter of traction converter: The power of the locomotive shall be reduced only by 1/4 (one fourth). In the event of isolation of auxiliary converter, load sharing to take place only after DJ tripping with P1 fault message.

v) Failure of one speed sensor element: The operation of the locomotive shall not be degraded and all traction motors shall remain operational.

vi) Breakdown of an auxiliary converter: The traction capacity of the locomotive shall not be affected as a result of the redundant design of the auxiliary converters.

vii) Control Electronics (VCU) shall have adequate redundancy so that a breakdown shall not affect the traction and braking operations of locomotive without need of cab change. Complete cab redundancy and processor level redundancy features shall be ensured and the same shall submitted as part of the design details. Reference may be taken from RDSO Modification Sheet No. RDSO/2014/EL/MS/0429, Rev. '0' dated 26.02.2014, RDSO/2014/EL/MS/0435, Rev.'0' dtd. 06.06.2014 and Modification Sheet No. RDSO/2017/EL/MS/0459, Rev.'0' dtd. 05.05.2017.

viii) Where the system design of the equipment incorporates component redundancy as the method of reducing the consequences of a single point failure, such redundancy shall not allow hidden faults to remain undetected.

ix) Hotel Load control processor in VCU shall have redundancy even though cab redundancy available (ex. STB1 isolated).

x) Control Electronics (VCU) shall able to work normal operation (shall not affect the traction and braking operations of locomotive) after rebooting the converter on run (VCU reset on run).

4.1.8 The protection/alarm/indication circuits shall 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 shall be made available to the Driver to enable corrective action to be taken in time.

4.1.9 RELIABILITY AND MAINTANIBILITY

In design and construction, reliability and maintainability shall be of paramount consideration. Supplier shall submit reliability calculations indicating MDBF (Mean Distance between Failures) for different devices, cards and sub-assemblies during design stage. Failure of propulsion equipment is defined as any defect arising out of the propulsion equipment causing the locomotive to not achieve the guaranteed performance as required in this specification and standard. The minimum MDBF of Traction Converter, Auxiliary Converter, Vehicle Control Unit and DDU shall not be less than 1,00,000 kilometres. The MDBF provided by the manufacturers shall be examined during field performance and the same shall be linked to FRPCPY of the concerned equipment. Adequate margin shall be provided to take into account ambient conditions prevailing in India.

Power modules for drive side and line side shall be interchangeable for ease of maintenance. Further the power modules shall be easily accessible and removable of same from the converter without dismounting the converter from locos.

4.1.10 High efficiency of equipment shall be important consideration, next only to high reliability. The components and technology used shall ensure very high efficiency of the converter. The expected efficiency with respect to vehicle load and speeds shall be furnished to IR. The efficiency of individual equipment such as Traction Converter and Auxiliary Converter shall also be submitted to IR. These measurements of efficiencies shall have to be organised by the Supplier at their cost and shall be witnessed by IR's representative.

4.1.11 Modular constructions shall be adopted wherever considered possible. Easy access for inspection/maintenance and minimum maintenance requirement shall be given special consideration in design and layout. Traction Converter shall be designed in such a way that main Transformer bushings and choke bushing must also be visible after opening of Traction Converter front door to check any oil leakage from bushing. In this reference, the scheduled maintenance activities shall be a part of design documents and have to be got approved along with design approval.

4.1.12 In the design and construction of IGBT based converter/inverter and associated control equipments, 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.

4.1.13 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 individual IGBTs should be driven by their gate drive unit with breakdown prediction mechanism of Vce saturation and GE low impedance detection performed by GDU to prevent the IGBT from electric stress or thermal stress. The current rating of all power semiconductor devices shall be such that the junction temperature has a minimum thermal margin of 10% with respect to maximum permissible junction temperature of power devices in the worst loading conditions and under the ambient conditions as specified.

4.1.14 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% shall be kept with respect to maximum permissible junction temperature of power devices declared by the manufacturer. This shall be demonstrated during the type test.

4.1.15 It shall be ensured that the stability & dynamic performance of Indian Railways electrical systems with the introduction of this locomotive shall meet the acceptance criterion as defined in IEC 62313. The total inductive power factor of the locomotive should adhere to the limits given in Table-1 of IEC 62313. Any technology/topology/configuration used in the locomotive systems/sub-systems/equipments shall maintain the stability & dynamic performance of the Indian Railways electrical system under all operating conditions.

4.1.16 The equipments for WAG9/WAG9H/WAP7/WAP5 shall be identical in all respects.

4.1.17 Energy metering (energy consumption and energy regeneration) function shall be integrated in the control software.

4.1.18 Marking: The major equipments/subassemblies shall bear marking and serial number. The equipment shall contain serial number and make of Supplier and located at a place (preferably to side of equipment) which is easily accessible and viewed. Also, the name plate should be engraved/punched with governing specification details and also the details of purchase order against which the particular equipment has been supplied.

(a) All equipments/cubicles shall contain name plates of anodized aluminum with engraved / punched letters.

(b) The inverter rating plate shall be marked with the following information:

(i) Type / Make

(ii) Contract number

(iii) Month and year of manufacture / batch no. / serial no.

(iv) Rating:

- kVA

- Input voltage range

- Output voltage, frequency and wave shape.

4.1.19 Pantograph bouncing upto 45 ms (limit of zero pressure contact) normally experienced in service shall not adversely affect the performance of propulsion equipment. Sufficient DC Link Capacitance, which shall not be less than 10mF in any case, shall be provided to avoid the issue of Tractive Effort/Braking Effort loss during train operation in whole range of designed speed of the locomotives. Higher and frequent pantograph bouncing period may be encountered during operation and suitable strategy shall be adopted without degradation of performance of the propulsion equipment. A detailed calculation/simulation shall be submitted with design document in this regard.

4.1.20 The modes of operations and functionality of the locomotives are detailed in Annexure-F.

4.1.21 Any new systems may be planned to be commissioned on locomotive in future like Radio Remote Control and Remote Diagnostic System. In such cases, supplier shall provide full cooperation for adaptability of these systems with their Propulsion System. The cooperation shall include minor design changes, hardware modifications and software changes without any extra cost to I.R.

4.1.22 The use of general purpose ICs should be encouraged and use of ASICs restricted for better maintainability.

4.1.23 Mode of Communication:

"Optical fiber cable (OFC)" system of communication shall be adopted as a medium of communication.

4.1.24 Major activities carried out by LP shall be recorded irrespective of the fault (like ZPT up/down, BLDJ close/open, forward or reverse direction selected etc.)

4.2 Traction converter

4.2.1 There are two traction converters identical in all respects shall be provided in one loco. It is expected to study in detail the existing interface of the GTO Converter with

the remaining equipment on the locomotive (e.g. Traction Motor, its speed and Temperature Sensors, Transformer with its series resonant choke, Harmonic Filter, Cooling Arrangement and Vehicle Control Unit etc.). It is also expected to study in detail the existing machine room layout, ducting, cable routing etc. on the locomotive. Site visit for this purpose can be arranged on prior intimation to the Production Unit. The main contactor of traction converter shall be located in such a location which is easily accessible for hassle free maintenance & replacement.

4.2.2 Following special features shall be provided to maximise the performance & reliability and minimise possibilities of trains being stalled in the section:

(a) Individual axle control shall be provided.

(b) Suitable redundancy shall be provided in the vital PCBs connected with safety and power supplies i.e. power supply cards, processor cards, controller cards etc., so that locomotive failure, degradation in performance and disabling the train is avoided in the event of their failure. [Further derated outputs for different failure for line/drive/controllers may be defined clearly for different sub-systems like SR, BUR, VCU, DDU.]

(c) The existing fault screen of the driver (fault messages displayed on driver display) shall remain same as in existing GTO locomotives with the adoption of IGBT traction converter except for following new messages needed due to individual axle control:

- Motor 1 – Bogie 1 isolated – reduced traction/braking
- Motor 2 – Bogie 1 isolated – reduced traction/braking
- Motor 3 – Bogie 1 isolated – reduced traction/braking
- Line converter 1 – Bogie 1 isolated – reduced traction/braking
- Line converter 2 – Bogie 1 isolated – reduced traction/braking
- Motor 1 – Bogie 2 isolated – reduced traction/braking
- Motor 2 – Bogie 2 isolated – reduced traction/braking
- Motor 3 – Bogie 2 isolated – reduced traction/braking
- Line converter 1 – Bogie 2 isolated – reduced traction/braking
- Line converter 2 – Bogie 2 isolated – reduced traction/braking

4.2.3 The wheel slip detection and correction system shall be an integral part of the control system of the traction 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. Maximum adhesion reduction during wet rail condition must not reduce below 20% of the dry rail adhesion. The adhesion control system shall be capable of giving high adhesion through a wheel slip control system of proven performance. The objective shall be to maximise the delivered draw bar pull through control system in conjunction with sanding.

4.2.4 The converter/inverter system shall be capable of withstanding the maximum short circuit current under fault conditions and these shall 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 shall be demonstrated during prototype tests as per the relevant clause of the IEC 61287-1 and other applicable IECs.

4.2.5 During the earth fault or phase to phase fault in the traction motor, protection scheme of the converter/ inverter shall ensure that the fault does not have any adverse impact

on the Performance of the converter/inverter leading only to the concerned TM getting isolated. Details shall be furnished by the Supplier of such a scheme.

4.2.6 Only dry type capacitors shall be used for dc link / harmonic filter / resonant circuits. Capacitors used in the sine filter & DC link shall be compliant to IEC 61881-3 and IEC 61071 and confirmation shall be submitted in this regard.

4.2.7 Automatic wheel diameter correction shall be integral part of the control system of the traction converter. Wheel diameter difference permissible shall be more than or equal to the present limits, which are as follows:

- Wheels on different axles of the same bogie : 8.0 mm
- Wheels on axles of the different bogies : 25.0 mm

4.2.8 The proposed equipments shall not violate the given space envelopes of the equipment to be replaced. Any needed change due to new equipment has to be demonstrated with the help of suitable drawings. The dimensions of the converter shall not exceed the existing foot print and no intermediate frame shall be allowed for mounting of traction converter as a separate part of converter.

Item	Envelope Dimensions (WxDxH) mm
IGBT converter with VCU interface and cooling pump.	3000x1100x2087
Cooling tower with water/air and oil/air exchanger	1450x1154x1510
Machine Room Blower	800x1100x1620

4.2.9 Existing principle of the machine room ventilation shall be kept unchanged.

4.2.10 Traction motor speed sensor and associated accessories:

(i) Active speed sensors with 120/200 teeth wheel ring duly approved by IR shall be provided.

(ii) Power supply for the speed sensor shall be from the electronics card of the converter. 2x2x0.5 shielded twisted cable shall be used for speed sensor signal and one shielded cable having single twisted pair to be used in the loco machine room for speed sensor power supply. Following shall be within the scope of supply of the Supplier:

- Active speed sensor with existing mechanical interface.
- Tooth wheel with existing mechanical interface.
- Sensor plate.
- Suitable male and female parts of the speed sensor connectors at the sensor plate with POKA-YOKE arrangement to avoid wrong placement of the connectors.
- The sensor connector at the converter end.

Note: Speed sensor shall be supplied as per CLW specification No. CLW/ES/03/0528 dated Nov'.12 or latest which may be taken from CLW. The drawing and details of location of speed sensor connectors used presently in GTO converter may be had from CLW and location of speed sensor connectors at converter shall be kept same as per the drawing to have same length of cable for speed sensor.

4.2.11 Existing input power connection methodology from transformer terminal to traction Converter terminal shall be used. Supplier shall use same transformer links and flexible links as per CLW specification no. CLW/ES/3/0138 or latest. If firm does not

require using the existing transformer link as per CLW specification No.CLW/ES/3/0138, then they will have to supply the suitable flexible links in consultation with IR.

4.2.12 Converter output

The motor converter output current ripple shall be such as to keep the torque pulsations and traction motor heating to a minimum. It is the Supplier's responsibility to make sure that output quality of the Traction Converter is entirely suitable for the existing traction motors. The motor converter shall generate the 3-phase output with higher pulsating frequencies and improved pulse pattern than with the existing GTO system.

4.2.13 The existing transformer, which is to be used, is provided with a filter winding. The resistance and inductance values of which have been given in Annexure B. The filter resistor and filter capacitor ratings are 2800 V, 0.2 ohm/40 kW & 0.2 ohm/60 kW and 0.4 mF, 2500 V, 80 A (bank capacity) respectively. During single bogie operation, filter adaption contactor (8.2) is opened thereby introducing an additional resistance. During normal operation, contactor 8.2 remains closed. The existing harmonic filter has to be considered while designing the system for interference limits. It is expected that with higher switching frequency of IGBT, this shall be sufficient to meet the stipulated harmonics requirements. It shall be possible to simplify the Harmonic Filter. In the design document, the filter arrangement required shall be indicated clearly, and if any modifications are required, it has to be done through choosing appropriate external RC elements, which shall then be provided to IR for necessary modification in the locomotive. Active harmonic compensation through line converter pulsing may be incorporated for the possibility to eliminate the filter. Increase in harmonic filter current during shift in pulsing of line converters should be avoided and traction converter software should make sure that any change in configuration of the line converters does not create a rise in current above 400A in filter winding. The details in this regard shall be submitted during design approval stage.

4.2.14 Mechanical Dimensions:

Dimensions of the existing Traction Converter are 3000 x 1100 x 2087 mm (WxDxH). The dimensions of the IGBT Traction shall not exceed these values. Detailed dimensional drawings can be made available at Production Units. The panel sheets used for fabrication of enclosure shall be of stainless steel grade 304 as per ASTM-A240 of minimum thickness 2.0 mm. The cabinet door material may be used aluminium alloy for light weight of the door. The quantity of fixing bolt per door shall not be more than 10 nos. Necessary FEM analysis of cabinet shall be submitted by supplier. Tolerance applied in the linear dimensions of GA drawings shall be as per General Tolerances IS 2102(Part 1): 1993, ISO 2768-1:1989).Mounting locations shall be of medium grade whereas outer dimensions shall be of coarse grade.

4.2.15 Cooling:

The present GTO Converter uses forced oil cooling. There is a common aluminium alloy heat exchanger module for both converter and transformer, but with different oil circuits. The blower is common. There are two cooling units, one for each bogie.

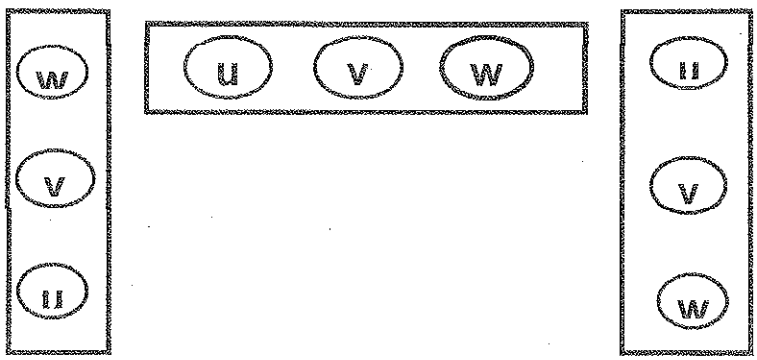
The Supplier shall use the existing radiator and cooling circuit with blower and pumps for the cooling of the Traction Converter. The coolant used for the converter shall be based on Organic Acid Technology (OAT)/Hybrid Organic Acid Technology (HOAT) and shall be mixture of water and ethylene glycol containing corrosion inhibitors and the ratio of ethylene glycol and demineralized water shall be 30:70. The form and

appearance of coolant shall be liquid green. Visibility of coolant level shall be provided in conservator of the converter and there shall be sufficient gap between maximum and minimum level. There shall also be a drain cock on the converter side to prevent spillage of coolant. The detailed drawings of the existing system can be obtained from CLW. Following shall also be ensured:

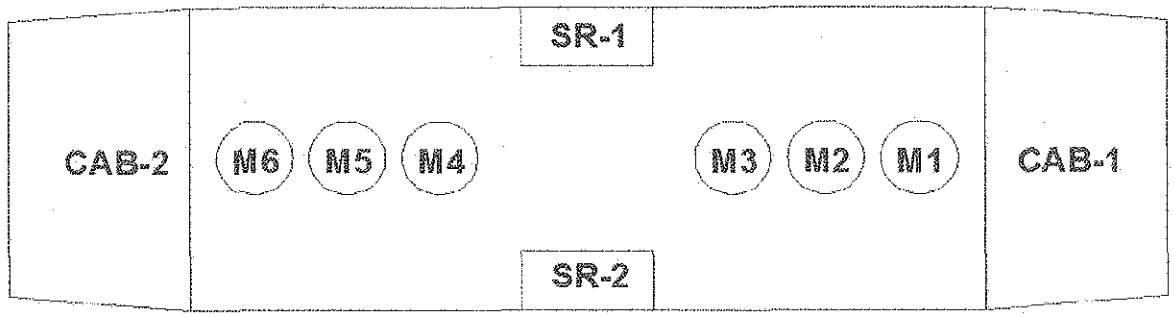
a. The coolant guage glass material should be Polycarbonate type and have sufficient strength so that cracks do not originate from fixing bolt hole area resulting in coolant leakage.
b. The coolant circuit should have breather arrangement to avoid coolant spillage/leakage due to air lock and fluctuation in coolant lever.
c. The coolant pump circulation system should have isolation cock arrangement for easy replacement of coolant motor/attention of coolant circuit.

4.2.16 MCB in HB panels & connectors in the converter side for 3-phase 415 V auxiliary supply, i.e., for pump/fan etc, in the Propulsion System shall be in the firm's scope of supply. One MPCB of rating 6.3-10 Amps in HB panel with provision of different settings shall be used for protection of cooling pump/fan in Traction Converter. Standard cable length as in GTO loco shall be adopted for cooling pump connection. Details and drawings for location of pump connection point at converter side may be had from CLW. No MCBs shall be used inside the traction converter. The coolant pump should be provided in such a location which is easily accessible by maintenance staff (preferably outside of SR). Separate MCB to be provided for cooling fan and cooling pump.

4.2.17 Standard orientation of Traction Motors as in existing GTO based traction converters and standard sequence of motor terminals at the converter end to be adopted as in existing GTO based converters. The same configuration shall be used by Production Units for the connections of Traction Motors. Supplier shall also adopt the standard lengths of the control cable and power cable as in case of GTO based converters. The orientation of traction motor and sequence of traction motor terminal is as below:



Sequence of motor terminal



Orientation of Traction Motor

4.2.18 The initialization time for IGBT based Traction Converter shall be kept as low as possible and loco shall be ready for operation within one minute after switching ON BL key.

4.2.19 Converter control electronics and IGBT modules enclosures shall comply with IP 54.

4.2.20: **Protection:** Following protections shall be provided in traction converter as a minimum:

a. Open circuit in traction winding;
b. Earth fault in AC input circuit, DC link and 3-phase load;
c. Input over voltage / under voltage;
d. Input over current;
e. DC link over voltage / under voltage;
f. DC link short circuit;
g. GDU optic link error;
h. Single phasing load;
i. Line to line short circuit due to dead short at motor terminals;
j. Thermal over loading of power modules;
k. Failures of power supply to control electronics;
l. Converter coolant pressure monitoring;
m. Converter coolant over temperature;
n. Harmonic filter overcurrent (external signal);
o. Transformer oil pressure (external signal);
p. Transformer oil temperature high (external signal);
q. Traction motor over speed (external signal);
r. Traction motor over temperature (external signal);
s. Auxiliary winding over current (external signal);
t. Hotel load winding overcurrent (external signal);

Protection limits for each of above shall be as per ABB protection scheme (ToT Doc no. 3EHP541784/785/ 786 & 3EHP541526 following control algorithm 3EHP541681 & 3EHW510068). Further DDS message for each protection shall be provided. The details of such protections, limits and DDS messages shall be submitted for review during design stage.

4.2.21 The main contactor used in the traction converter must be of EMC type (not motorized contactor). The main contactor must not open at every DJ opening like neutral section thereby reducing its duty cycle. Main contactor opening and closing should be based on node progression and DC link voltage.

4.3 Auxiliary System:

4.3.1 Auxiliary system shall consist of Auxiliary Converters, Battery Charger and associated protection system. The Auxiliary system shall be galvanically isolated from the traction power system. Auxiliary system design shall ensure that there is no surge / spike in the output voltage between phase to phase and with respect to earth. The common mode output voltage (with respect to earth) shall be as low as possible, preferably zero.

4.3.2 Auxiliary Converter shall be IGBT based and forced air-cooled. However thyristors can be used on input side. The control shall be microprocessor / micro-controller based with diagnostic features. Protection from overload/short circuit, single phasing and any other protection considered necessary for reliable functioning shall be provided. The output of Auxiliary converter shall be SINUSOIDAL. Design of snubber circuit for thyristor shall be ensured so that overshoot ratio is kept minimum.

4.3.3 Three Auxiliary converters (BUR1, BUR2 and BUR3) identical in all respects each with 130 kVA capacity and battery-charging unit (details in clause 4.3.4) shall be provided in one loco.

4.3.4 Converter Ratings (BUR1, BUR2 & BUR3):

A INPUT

(a)	Voltage	:	1000V single phase 50 Hz at a catenary voltage of 25 kV. The catenary voltage can vary in the range as specified in clause 2.2 of this specification.
(b)	Frequency	:	50 Hz ± 8%
(c)	Power Factor	:	0.8 or more (at full load) between OHE voltage 19kV to 27.5kV and min. 0.55 above 27.5 kV.
(d)	Total Harmonic Distortion (Current)	:	To be kept to minimum, manufacturer shall indicate the optimized value at full load.
(e)	Winding Details	:	334 kVA / 5.82% Impedance / 258.58 mΩ
(f)	Other Details	:	A R-C snubber is placed across the auxiliary winding with R = 22 Ohm, 320W and C = 0.66 micro Farad, 2000V. In addition, toroid cores are inserted in the input cables to minimize the di/dt and interaction between multiple converters across same winding. It is to ensure that offered converter is protected in all operating conditions.

B OUTPUT

(i) SINUSOIDAL AC, 3 Phase

(a)	AC Voltage (L-L)	:	415 V ± 5%
(b)	Nominal Output Frequency	:	50 Hz ± 3%
(c)	KVA output	:	130 kVA
(d)	Short time current rating	:	Same as overload rating of existing GTO based 3 x 100 kVA Auxiliary Converter.
(e)	Total harmonic distortion (THD) in the output voltage to the 3-phase motor	:	Less than 10%.
(f)	dv / dt	:	Less than 500V/Microsecond
(g)	The auxiliary converter shall be suitable for generating 3-phase AC output at multiple voltages and frequencies as detailed in para 4.3.7 below		
(ii)	Nominal DC Output	:	110V, 80A with current ripple less than 5% and voltage regulation ±5%, with battery current maximum of 110A.
		:	The Battery Charger characteristics shall be suitable for charging the existing 199 AH Ni – Cd battery & supplying the 110V load in 3-phase locomotives.

Note: Rated capacity of 130 kVA is expected for input voltage range as specified in clause 2.2 of this specification. However, degraded performance in terms of lower output voltage or frequency is acceptable below the range specified and manufacturer shall specify the extent of degraded performance. It shall not be possible to regulate the duty cycle of the loads.

The existing smoothing choke, which is rated at 155A (Max.190A) shall be used in the Auxiliary Converter (3X130 kVA).
The details of the existing smoothing choke are as below:

Pos. : 51.3
Type : 6GOD120
Quantity : 1 Three phase choke
Location : Inside transformer tank
Data : Refer to specification No. 3EHE 428048

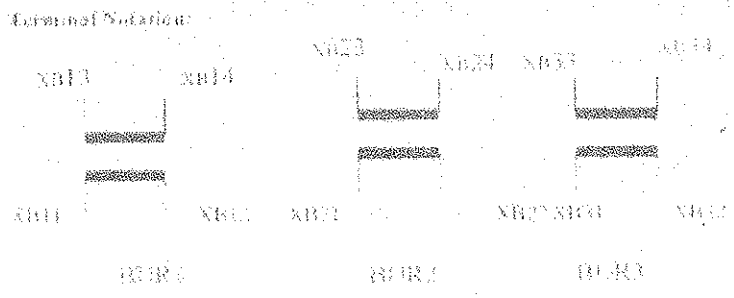
Inductance value of each BUR choke at different currents:

0 A : 30 mH
120 A : 30 mH
155 A : 26 mH
190 A : 20 mH

Tolerance : -0%, not specified
Frequency : 100 Hz
Current Nominal : 155 A
Max. : 190 A

Ripple	:	38.6%
Max.	:	50.2%
Losses at nom	:	12 kW + 15% total

Terminal Notations:



Each choke consists of a magnetic frame. The chokes are arranged in a stack. Since asymmetric voltages are applied across these, the chokes are decoupled. The DC link elements are designed for a nominal power of 100 kVA.

4.3.5 **Load Pattern:** The normal & emergency loadings are shown in Annexure C.

4.3.5.1 Three phase auxiliary load:

Auxiliary loads on individual BUR, in normal and fault conditions shall be distributed as detailed in Annexure C.

Auxiliary converter shall be in a position to soft start the loads using variable voltage variable frequency control.

4.3.5.2 DC load: The locomotive control circuit, loco head light, flasher light etc. are fed through 110V DC circuit containing locomotive battery.

4.3.5.3 Reconnection of the loads under emergency:

If one of the auxiliary converters fails then the provision is made for continued operation with reconnection of loads. The reconnection of loads is done with the help of contactors with interlocking feature. In case of isolation of one auxiliary converter, other two must take full load so that derating of loco due to isolation of Auxiliary Converter shall not take place. See Annexure C for the proposed connection. These contactors are controlled by the vehicle control electronics. The necessary actions for reconnection shall be taken by vehicle control electronics.

4.3.5.4 The auxiliary converter shall have provision for giving suitable supply for cab air conditioning and any other equipment to be provided in future.

4.3.5.5 At present, TM Blowers start running upon closure of VCB and continue to run even if Traction Motor temperature is not high & locomotive is at standstill. Energy optimisation shall be done by supplier by running auxiliaries at various speeds through software/hardware by sensing temperature of traction motor and transformer. Further details shall be worked out by supplier in association with IR during detailed design stage. There should be a provision to run the auxiliary load by auxiliary converter as per energy optimization scheme issued vide RDSO Mod Sheet No. RDSO/2020/EL/MS/0482 with latest revision.

4.3.6 Protection:

4.3.6.1 The devices used in the inverter shall be protected against high rate of rise of voltage & current, line transient surge, switching surges etc. The converters shall be protected against:

(a) Open circuit in auxiliary winding
(b) Ground fault in AC input circuit
(c) Ground fault in 3-phase load
(d) Auxiliary converter phase fault
(e) Line to line short circuit due to dead short at motor terminals
(f) Thermal over loading
(g) Fuse failure in converter
(h) High / low voltage in DC link
(i) Failures of power supply to control electronics
(j) DC link short circuit
(k) Input over voltage / under voltage
(l) Input over current
(m) Single phasing load
(n) Output over current

The details of such protection shall be submitted for review during design stage.

4.3.6.2 The equipment shall be protected against internal transient, spikes and surges as per limit laid down as per IEC 60571: 2012

4.3.7 Multiple voltage / frequency operation:

The energy conservation feature through multi-level ventilation / cooling for 3x130 kVA IGBT based Auxiliary Converter shall be provided and frequency step for multi operation shall be as follows:

<table>
<tr><th>Vent level</th><th>All BUR OK</th><th>BUR-1 isolated</th><th>BUR-2 isolated</th><th>BUR-3 isolated</th></tr>
<tr><td>0</td><td>BUR-1: 0
BUR-2: 50Hz
BUR-3: 0-50Hz</td><td colspan="3" rowspan="3">NA</td></tr>
<tr><td>1</td><td rowspan="3">BUR-1: 44Hz
BUR-2: 50Hz
BUR-3: 0-50Hz</td></tr>
<tr><td>2</td></tr>
<tr><td>3</td><td>BUR-1:0
BUR-2: 44Hz
BUR-3: 0-50Hz</td><td>BUR-1:44Hz
BUR-2: 0
BUR-3: 0-50Hz</td><td>BUR-1:44Hz
BUR-2: 0-50Hz
BUR-3: 0</td></tr>
<tr><td>3A</td><td>NA</td></tr>
</table>

4.3.8 Mechanical dimensions:

The spaces for retro fitment of auxiliary converter in place of existing equipment are mentioned under. The changes if any are to be agreed to between Railways and the Supplier. It is to be ensured that the above equipment shall be fitted in existing types of locos of IR namely WAG9,WAG9H, WAP7 and WAP5 and supplier shall make use of existing mounting arrangement used in GTO based auxiliary converter or necessary adaptation for installation shall be provided by supplier. Tolerance applied in the linear dimensions of GA drawings shall be as per General Tolerances IS 2102(Part 1): 1993, ISO 2768-1:1989).Mounting locations shall be of medium grade whereas outer dimensions shall be of coarse grade.

Envelope size of the space available in the locomotive for mounting the equipment (all dimensions are in mm) for retro fitment on WAP7 / WAG9/WAG9H/WAP5 locos, shall be as under:-

		Overall Size	Mounting Dimensions
(i)	Cubicle 1	1160 x 1020 x 1860 (LxDxH)	1120 x 900 (LxW)
(ii)	Cubicle 2	1520 x 1020 x 1860 (LxDxH)	1480 x 900 (LxW)

Note: A. A gap of 50 to 100 mm only is available between roof and equipment in the locomotive and hence cooling system design shall be done accordingly.

B. Cubicle 1 houses one and cubicle 2 hoses two fully identical 130 kVA converter as described in clause 4.3 of this specification.

C. Design details shall include power loss calculation considering existing cooling system.

4.3.9 The weight of the Auxiliary converter cubicles are approx. 608 kg for cubicle –1 (BUR-1) and 1130 kg for cubicle –2 (BUR 2 & BUR 3).

4.3.10 Enclosure:

4.3.10.1 The panel sheets used for fabrication of enclosure shall be of stainless steel grade 304 as per ASTM-A240 of minimum thickness 2.0 mm. The cabinet door material may be used aluminium alloy for light weight of the door. Necessary FEM analysis of cabinet shall be submitted by supplier.

4.3.10.2 Enclosure would be as per TOT design documents for auxiliary converter of 3-phase loco. Any alternative design meeting functional requirement shall be offered with full details for IR's scrutiny and approval.

4.3.10.3 The enclosure for electronics shall be free from dust and moisture. Design of cooling heat exchanger shall be done to ensure temperature difference less than 10 deg. Centigrade across the heat exchanger. This will be demonstrated during the type test. Control electronics and power modules enclosures shall comply with IP 54 as per IEC-60529.

4.3.11 Cooling:

From machine room blowers, a part of the cooling air is guided to the existing auxiliary converter cooling. The heat losses in the BUR are carried away through the heat exchanger. The ventilation air guiding ducts from the machine roof to cubicle 1 & 2 provide following air values:

Cubicle 1

Air flow rate	Front	:	1100 m^3/h
	Rear	:	550 m^3/h
Air speed	Front	:	2.5 m/s
	Rear	:	5.0 m/s
Pressure	Front	:	30 Pa
	Rear	:	6 Pa

Cubicle 1 & 2 provide following air values:

Cubicle 2

Air flow rate	Front	:	1700 m^3/h
	Rear	:	1100 m^3/h
Air speed	Front	:	5.0 m/s
	Rear	:	5.0 m/s
Pressure	Front	:	30 Pa
	Rear	:	20 Pa

The existing arrangement for the cooling of auxiliary converter was initially designed as per GTO auxiliary converter design. Also in GTO auxiliary converter, there are ventilation openings at both front and rear ends on top of auxiliary converter. Therefore, provision may be made for optimum use of air from front/rear opening for cooling of auxiliary converter.

In case of MRB failure there is no alternate cooling arrangement for modules and electronic cards of auxiliary converter. Provision for cooling blower/cooling fan (operating at 230V or 450V) may be made as an alternate arrangement.

4.3.12 **Locomotive cable interface:** It is proposed that the cables for connection to the locomotive shall be in the bottom of the panel. Following are the sizes of various cables proposed to be used. However, this may change as per the requirements and needs and shall be discussed and finalized after placement of order EB irradiated cables shall be used for internal wiring.

(a) Transformer auxiliary winding to input of Auxiliary converter panel – 70 mm^2 cable.

(b) Output of Auxiliary converter - 50 mm^2 cable.

(c) Battery charger to battery base – Two 10 mm^2 cable.

Control cables are connected from upper inside of the cubicle through a round socket connector. However, finalization of cable outlets shall be done during design approval after award of contract.

Location of input & output terminal shall be same as the one in existing Aux. converter to provide for interchangeability of different makes of Aux. converter.

4.3.13 General design feature:

4.3.13.1 Safety factor:

(a) In the circuit configuration, 25% safety margin in the rating of both voltage and current under worst conditions is to be ensured. This shall be established in the design details with calculation.

(b) A minimum thermal margin of 10% for junction temperature under worst operating condition for the power devices is required. Over load margins and duration are to be furnished.

4.3.13.2 Current density of the bus bars: less than 4A / sq.mm.

4.3.13.3 Acoustic Noise: Acoustic Noise generated by circuits and components shall be as low as possible, less than 80 dB (A) at a distance of 1 M from the equipment.

4.3.13.4 The cards shall be provided with LED indication to show the health of cards, to assist maintenance and operating personnel in trouble shooting.

4.3.13.5 The power portion of the equipment shall be suitably protected to prevent accidental contact. The shields and screens shall be properly earthed.

4.3.13.6 Cable: The use of wires / cables shall be reduced to minimum. Bus Bars shall be high grade copper and insulated bus bar is preferable. The wires / cables shall be of high grade, copper with halogen free thin walled insulations. All the cable terminations shall be made through crimped sockets / lugs and wires with circuit and diagram furnished. Each cable / wire shall be numbered at both ends for easy identification. The use of pre-insulated lugs suitable for double crimp for insulation and conductor is recommended. Current collection through threads shall be avoided and terminals of adequate size shall be provided.

4.3.13.7 Cable grommets / glands of suitable size as required for input and output cables shall be provided at cable entry / exit.

4.3.13.8 Fitment of MCB-100:100: MCB-100 (Circuit Breaker for battery charger), if required, should be provided on the front/ left side wall (near machine room blower-2) or at the top of Auxiliary converter-2 such that it should be easily accessible by the Loco Pilot and maintenance staff, the output of MCB-100 shall be connected directly to the input of battery charger. Mounting of MCB-100 should be such that it should be possible to operate it without opening the front door of Auxiliary converter-2. While opening the door of Auxiliary converter-2 during maintenance it shall be ensured that the position of MCB-100 in not disturbed. MCB-100 must be provided on left side wall.

4.3.13.9 Presently Ferrite Cores as per CLW specification no. CLW/ES/03/0431 are being provided at the input supply cable connecting to the Auxiliary Converter. The manufacturer should ascertain the requirement of these ferrite cores and necessary action may be taken to incorporate the same in IGBT based Auxiliary converter of their make, as Production Units will not be providing any ferrite core in input cable in future. The supplier will be responsible for proper working of Auxiliary Converter in absence of ferrite cores being used presently and the auxiliary converter should not cause any interference to power/control circuitry of locomotive and equipments installed nearby Railway tracks.

4.4 Electronics, Control and Communication:

4.4.1 The general provisions of this para shall be applicable to the Electronics used for Traction and Auxiliary Converters also. The electronics used shall conform to IEC-60571. However, due to higher ambient temperature in India, it shall be suitable for working for short time (at least 15 minutes) at high temperatures as expected to be encountered in locomotive standing under sun (refer to clause 2.3 of this specification). Therefore there shall be no requirement of pre-cooling of the electronics on locomotive standing in summer sun for long duration. The electronic control equipments shall be protected against unavoidable EMI in the machine compartment. The electronic cards (DIO&AIO) shall be provided with MOSFETS instead of reed relays.

4.4.2 Control and communication shall be based on open control architecture and compliant to IEC-61375 "Train Communication Network" protocol or any other superior, internationally published protocol. The programmable devices shall be programmed using language compliant to IEC-61131, if PLCs (Programmable Logic Control) are used.

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

4.4.4 The control system shall integrate the task of fault diagnostics and display in addition to control task. It shall be capable of real time monitoring the status of all the vital equipment continuously and occurrence of faults. It shall also take appropriate protective action and shut down the equipment wherever necessary. Features of self-check, calibration and plausibility checks shall be incorporated in the design. The software involving real time monitoring and equipment data capturing shall be submitted during design approval stage and same shall be demonstrated during prototype test.

4.4.5 The vehicle control unit (VCU) has to interface with the existing brake system of locomotive as well as new brake system as per RDSO Specification no. "RDSO/2017/EL/SPEC/0126 (latest version), for Computer/Microprocessor controlled air brake system with advance features. Presently E-70 brake system of M/s D&M / Faively Transport and CCB System of M/s Knorr-Bremse are used on of locomotives. However, in case the new brake system is present in the locomotive, then regenerative braking shall be act as primary braking of the Locomotive i.e. whenever A9 is applied by the driver, regenerative braking shall be applied in the locomotive and pneumatic braking in the load. In case the regenerative brake has broken down due to OHE failure or any other reason, the regenerative brake effort substitute to pneumatic brakes application in locomotive as well as in the train. The driver shall be able to control the train with regenerative brakes and/or using the automatic train brakes. The interface hardware and software shall be designed accordingly. The automatic Flasher operation (in case of train parting) and the Vigilance Control functionality, which are available at present through the brake system, shall be implemented. In addition, provision shall be kept to interface with the brake system through multiplexed pair of wire on RS-485 protocol.

4.4.6 The VCU shall have a diagnostics computer, with non-volatile memory, to store all the relevant diagnostic data. On occurrence of each fault related to propulsion system in the scope of this specification, 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 shall be facility to capture post trigger and pre-trigger background information. The diagnostic computer shall specify diagnostic of fault up to card level. The diagnostic system shall be able to identify and log all faults on the locomotive and such data shall be stored in the diagnostic computer for a period of not less than 100 days. Application software shall be provided to facilitate the fault diagnosis and the analysis of equipment wise failures. The steps required for investigation to be done by maintenance staff shall be displayed in simple language along with background information. Such software shall be compatible for working on commercially available operating systems. In addition, provision shall be made to store all the vehicle level monitoring signal data with an interval of one second for bare minimum of 72 hours.

The event of fault, concerned diagnostic processor must record all pre fault data (5 sec) and post fault data (3 sec) and store all the environment and MVB variable in a format that can be later analyzed as a waveform pattern in diagnostic tool. Approval for the list of environmental and MVB variables that are to be recorded has to be taken from IR at design stage.

4.4.7 The vehicle control unit (VCU) shall also provide on-line, context sensitive trouble shooting assistance to the driver in case of any fault, through the driver's display.

4.4.8 It shall be possible to access all the processors within a vehicle 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 shall be built in the VCU so that standard laptops shall be directly plugged to the VCU without any special interface. Provision shall also be made for downloading of DDS data from DDU in addition to VCU. Supply of a suitable software tool and laptops is included in the scope. Using this tool, it shall be possible to reset the diagnostic memory for further recording. This tool shall also provide detailed off line analysis facility. Preferably Ethernet/ USB 2.0/ USB3.0/RS232 interface shall be used. Cyber security shall be followed as per standard CLC/TS 50701.

4.4.9 Supply of a suitable visualization software tool, which would run in a laptop connected to the vehicle control Unit, for visualizing the process variables, is within the scope of supply. Using this tool, it is expected to visualize any process variable on the screen, record and temporarily force its value. Recording shall be both in numerical and graphical form.

4.4.10 It shall 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 like currents, horse powers, temperatures, pressures, speeds etc., for adjusting the characteristic within permissible range, changing preset values, limits, characteristics etc. and behavior of the locomotive in general, and add/alter the protection features, if so required in future in order to improve the operation of locomotive. It shall be possible to configure these parameters through laptop. A menu driven easy to use application software shall be provided for loading on the laptop for this purpose. Password protection shall be provided to safeguard against misuse.

4.4.11 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. The cooling arrangement of the electronics of the traction converter, auxiliary converter and the VCU shall be designed so that the temperature adjacent to the electronic cards remains below 45 °C (degrees Celsius) while the locomotive is operating. Peltier module may be provided for cooing arrangement for electronics of Traction Converter & Vehicle Control Unit. Alternatively, the cooling arrangement of the electronics of the power converter, auxiliary converter and the VCU shall be designed so that at least 20 deg Celsius margin is maintained between temperature adjacent to the electronic cards and the maximum temperature allowed adjacent to the electronic cards. This shall be demonstrated during the type test. Also, periodicity of maintenance of these cooling arrangement should be clearly specified in the maintenance and troubleshooting manual supplied along with the system.

4.4.12 The electronic cards shall be mechanically coded to ensure that insertion of card in wrong slot is not possible. Two additional expansion slots shall be kept to integrate additional system in future or firm should have sufficient spare channels (DIO&AIO) for future requirement. The firms can also supply wall mounting or din rail mounting type arrangement for PCB.

4.4.13 Capacitors shall be liberally rated, keeping in view the high ambient in India, vibrations of electric rolling stock and electrical surges expected during operation. Indian Railways have experienced high failure rates of electrolytic mounted on

PCBs of electronic cards due to high operating temperature / voltage / current vis-à-vis designed operating temperature/voltage/current. This aspect shall be especially kept in view during design. Dry type of capacitors shall preferably be used. Expected life of the cards, and electronics in general shall be at least 18 years under working conditions.

4.4.14 Maintenance of electronic systems:

a) On-board diagnostic shall be used on the locomotive to discriminate between fault on the rest of the locomotive and fault on the electronic equipment.

b) Shall the electronic equipment found faulty, the on board diagnostic shall enable fault finding to be carried out at module level.

4.4.15 It has been IR's experience that the temperature inside the machine room near electronic cubicle of WAG9, WAG9H, WAP7 and WAP5 locos rises to more than 65 deg Celsius during summer season when ambient temperature is as high as 50 deg Celsius. The Supplier shall do trials of temperature measurement 12 mm away from card by suitable equipment, such as thermocouple, in working condition of loco to demonstrate the temperature rise during field trial period. The same will also be validated during type test.

4.4.16 IR shall facilitate doing trials, if desired by Supplier, on existing WAG9H, WAG9, WAP7 & WAP5 locos for temperature rise inside machine room near electronic cubicle and dust ingress in machine room to appreciate Indian conditions so as to consider appropriate design of electronics and suitable filters and blowers.

4.4.17 In the existing system, the electronic racks are mounted within a sealed casing located at low voltage cubicles (SB1 & SB2). The air from the machine room blower indirectly cools the casing. In this offer also, the racks are to be mounted at the same locations to avoid change in the locomotive cable harness. The suppliers may choose to adopt the same mechanical system as existing today, which means the racks are mounted within the casing and the casing is cooled indirectly. In such a case, supply of rack integrated with casing and heat exchanger shall be part of the supply. The offered rack shall be having its own cooling and ventilation arrangement. The physical location of present VCU1 and VCU2 shall be retained. The offered VCU racks are to be mounted within the mechanical space envelope existing. Presently the rack which comes in a casing is indirectly cooled by a heat exchanger mounted on this casing through which the machine room air passes. The rack is a 6U card cage. While the location has to be retained within the constraints of existing space envelope and mounting arrangement, the requirement of the cooling shall be met either by utilizing the existing arrangement or by providing a suitable alternative within existing space envelop and airflow. Supply of rack casing and the cooling arrangement is part of the scope of supply.

The essence is as follows:

- New racks are to be accommodated in casing on which SB1/2 cubicles shall be mounted like used presently.
- The Supplier may or may not utilize the present indirect cooling arrangement using MR air and BEHR Radiator depending on the design. In case the heat exchanger is not required opening has to be suitably blanked at this point by the Supplier.
- The Supplier has to make his own arrangement for internal circulation of air to avoid hot spots. Presently a fan tray is mounted below the rack.

- Casing shall be within the scope of supply.
- External heat exchanger is also part of the supply in case the design so needs it.

At present, the vehicle control units are housed in two racks viz. rack type HVB494A33 and HVB494A34 for vehicle control units VCU1 & VCU2 respectively. The interconnections of VCU1/VCU2 with control rack of Traction Converter and Auxiliary Converter is given in annexure-D.

However, VCU, instead of being a multiple stacked processor, should be of a single processor unit capable of processing the entire application software logic. Considering this, manufacturers shall try to incorporate minimal number of cards in VCU.

Ethernet technology has been widely deployed for train communication networks (TCN) and also onboard EDs (End Devices). The international IEC standard has structured the Ethernet based TCN into a hierarchical way with ETB (Ethernet Train Backbone, referred to IEC61375-2-5) and ECN (Ethernet Consist Network, referred to IEC61375-3-4) shall be preferred.

4.4.18 IR prefers to retain the existing cable looms with connectors (for I/Os and battery power) without any change, so that the same shall be plugged on to the new system under consideration. It is expected to study the present arrangement and expected to comment specifically about the retention of present arrangement without any change. Cables supplied by manufacturer shall withstand high operating temperatures experienced in Indian conditions so as to avoid the premature failure of control cables due to insulation perishing and overheating leadings to insulation becoming brittle.

4.4.19 Special Comment on Control Cabling from Driver's Desk:

In existing scheme, the driver's desk is physically wired to the VCU1 and VCU2 cubicles. Alternative schemes may also be proposed involving intelligent I/Os which shall reside in the driver's desk for capturing and actuating various drivers' interfaces communicate with VCU over CAN/MVB and the existing cabling then can be saved upon. This however shall be quoted as an option and the IR shall decide upon the relative merits of existing scheme and this alternative.

4.4.20 Maximum mechanical Dimension (envelope) of VCU housing Case

Length - 760 mm
Width - 502 mm
Height - 560 mm

4.4.21 Isolation of individual traction motor shall be made possible through DDU itself from both cabs. Speed and temperature monitoring of isolated TM shall be avoided to prevent generation of speed disturbance messages.

4.5 Driver's Display:

4.5.1 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 and status of various important parameters as selected by driver maintenance staff or as required for the satisfactory system operation. etc. The display shall be menu driven. The interface with the driver shall be very simple considering average level of proficiency of drivers in handling electronic devices.

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

4.5.3 Selection of display medium shall take into account high ambient temperature and light, due to direct sunlight on the driver's desk. Backlit arrangement shall be provided for all time visibility. The display system shall be protected against dust and moisture. The display system along with its controls shall be very rugged for repeated rough use. The display unit should have sufficient mechanical strength so as to overcome the issue of cracks developing in display unit and fixing arrangement should be so designed that moisture entry into the unit & its connectors is avoided.

4.5.4 Display units shall be accommodated in same space envelop of existing display units.

4.5.5 The display system shall be protected against dust and moisture to an IP rating of IP 65.

4.6 Insulating materials:

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.

4.7 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 shall 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. The present arrangement of safety interlocking of the major equipment may be studied and appropriate arrangement for the equipment under the scope may be offered.

Voltage indicator shall be provided on top of the converter for indication of presence of high voltage to ensure safety of maintenance personnel.

A sensitive reliable protection arrangement against earth fault shall be provided.

All electrical circuits shall be fully insulated from the superstructure on both positive and negative sides. 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 shall any fire take place, the effect shall be minimized and no spread of fire shall take place. Materials, which are not fire-retardant, shall not be used.

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.

4.8 Event recorder

The event recorder shall monitor and record various critical events so that data is available for analysis to assist in determining the cause of accident, incident or operating irregularities. There shall be one event recorder and it shall be designed in such a way so as to provide an intelligence based recording of the following parameters against the time axis (time interval shall be decided by recorder itself whenever there is a change in the respective parameter). The minimum recording parameter shall be as per EN 62625-1: 2013 or latest. Event recorder shall have one crash protected memory (not less than 8 GB) and one data logging memory (not less than 32 GB) for recording of data. The memory shall be allocated to store short term data with sampling rate of one second for last 72 (seventy two) hours in each flash protected memory and long term data for 90 days with sampling rate of 20 second in data logging memory.

The following (non-limited to below mentioned) parameters shall be recorded:

(a) Speed in Kmph;
(b) OHE voltage;
(c) OHE current;
(d) input power factor
(e) tractive/braking effort & master controller handle position;
(f) battery voltage;
(g) brake pipe & main reservoir pressure (in Kg/cm^2);
(h) automatic brake handle position (i.e. running/minimum reduction/ full service/ emergency/ release)
(i) direct brake handle position (i.e. release/ application zone/ fully applied)
(j) EBV selector switch position (i.e. lead/trail/ test/ banker/ helper)
(k) Emergency brake status (i.e. release/ applied by push button/ applied by ALP/ applied by VCD/ applied by brake controller/ applied by auto brake handle/ applied by over speed)
(l) brake cylinder pressure BC-1/BC-2 (in Kg/cm^2);
(m) parking brake status (i.e. released/ applied in bogie-1/ applied in bogie-2);
(n) air flow value from BCV
(o) cab1/cab2 activated cab;
(p) pantograph up/down position;
(q) status of main circuit breaker i.e., open/close;
(r) mode of operation i.e., traction mode/braking mode;
(s) direction of travel i.e., forward/reverse with respect to activated cab;
(t) head light status ON/OFF;
(u) flasher light status ON/OFF;
(v) horn status ON/OFF;
(w) status of penalty brake application;
(x) emergency brake pressure switch status;
(y) status of emergency brake by assistant driver;
(z) wiper ON/OFF;
(aa) vigilance control;
(bb) wheel slip/slide;

(cc) temperature of major assemblies and
(dd) any other parameters considered necessary.

The event recorder shall be designed to:

(i) permit rapid extraction and analysis of data for the purpose of monitoring driver or Locomotive system;
(ii) assist retrieval of data after an incident or accident; and
(iii) mitigate the effects on recorded data of foreseeable impact or derailment.

All forms of data download shall be read only and the data shall be protected against unauthorized corruption or deletion. The data recorder shall be capable of downloading whilst the Locomotive is moving, without any interruption in continuous recording during such download. The recorder shall record each occurrence of a download as an event.

The event recorder shall be designed and constructed to ensure the integrity of the recorded data and the ability to extract data following an incident. The event recorder shall be tested in accordance with a recognised international standard such as the UK Railway Group Standard GM/RT2472 and EN 62625-1:2013 or latest.

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CHAPTER 5

INSPECTION, TESTS AND TRIALS

5.1 The propulsion system shall be tested on a combined test bed generally in accordance with the IEC 61377. 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. Dry Heat test of the Electronics shall be carried out at 80° C as per IEC: 60571. All optional tests mentioned in various standards shall also be carried out. Details shall be worked out during design approval.

The electronic cards used in the equipments shall be subjected to burn in test for minimum 45 hrs as per temperature cycle in Annexure E. The cards shall be kept energized during the test. The functional test each card shall be carried out after the burn in test.

5.2 Type tests, combined tests and routine tests shall be carried out by the Supplier at his own responsibility and cost and in the presence of and to the satisfaction of representatives of IR.

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

5.4 The Supplier shall formulate and submit type and routine test protocol / plan at design approval stage for approval of IR before undertaking manufacture. It shall, however, be open for IR to waive some of tests in case of equipment and sub-assemblies, where the manufacturer can establish to the satisfaction of IR that such tests have already been carried out earlier on the same equipment and where equipment has been proved in prolonged service.

5.5 First locomotives equipped with the propulsion system supplied as per this specification shall be subjected to the following tests to satisfy Indian Railways regarding operational performance, capability and safety:-

(i) Dynamometer car tests to ascertain starting and rolling resistance of the locomotive and to prove tractive effort / braking effort – speed characteristics.

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

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

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

5.6 Wheel slip and adhesion characteristics shall receive proper attention during the tests and trials under different track conditions.

5.7 The locomotive shall also be evaluated during operation under actual load conditions. These shall be termed as "Service Trials". Apart from checking on the repeatability of the operational performance under different conditions, these tests shall also enable practical evaluation of the maintainability, accessibility of components, reliability in service and such other aspects, which have been envisaged in this specification.

5.8 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 IR for final approval.

5.9 The components of Traction/Auxiliary Converter etc. shall not be subjected to type tests but their test certificates shall be submitted to IR.

5.10 Initialization time of traction converter shall be demonstrated during type test and it should be as per clause 4.2.18

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Annexure A

DESIGN DATA, CALCULATIONS AND DRAWINGS TO BE SUBMITTED BY THE SUPPLIER

1.1 Design data shall include following particulars:

1.1.1. Traction, & Auxiliary Converter / Inverter: Make and type, number of cubicles per loco, thermal characteristics of IGBTs, arrangement of devices, margin in current, voltage and junction temperature, heat sink details of IGBTs, cooling system design details including air/water flow rates and arrangement of filtered air, noise level, configuration with detail calculation of branch wise current providing adequacy of the devices used, Rating of each IGBT, Thermal margin with calculations, overall dimensions and weight. Details of the capacitor for DC link as well as resonance circuit, if provided, details of the protection of power converter, the designed power loss in the converter, justification of components rating used.

For Traction Converter only: Performance plot for transformer secondary current at different voltages as function of speed during motoring and braking, Traction motor phase current as a function of speed, Traction converter efficiency as a function of speed, line voltage during motoring and braking, Traction motor Line-Line voltage as a function of speed; Modulation index as function of switching frequency for motoring and braking mode, PWM switching strategy for line converter and drive inverter with variation in switching frequency for motoring and braking.

1.1.2. Vehicle control unit and diagnostic system: Make and type, details of microprocessor, Complete functional description, details of faults to be displayed in driving cab and stored in permanent memory, details of complete cab redundancy and processor level redundancy features, procedure for down loading the details of faults from memory, details of all protection schemes of all equipments, details of control for converter, DC link, inverter, traction motor, braking etc.

1.1.3. Smoothing Reactor / Filters: Make and type, number and rating of the coils, inductance and ripple characteristics up to 1.5 times the rated current, details of the conductor and insulation system, current density, losses, temperature rise limit, details of cooling system, dielectric test voltages, overall dimensions and weight of the equipment.

1.2 Design Calculations shall include:-

a) Weight and centre gravity of each equipment with weight unbalance calculations etc.

b) Adhesion calculation.

c) System performance calculations.

d) Cooling system calculations.

e) Tractive and braking effort vs. speed curves showing balancing speed.

f) Detailed step-wise calculations for equipment ratings and performance requirement.

g) Curves of efficiency, power factor, frequency, slip as a function of speed.

h) Harmonic calculations.

i) Reliability predictions of each equipment at 40°C.

1.3 Drawings:-

1. Schematic diagram of power, dynamic braking, control and auxiliary circuits including multiple operations.
2. Mounting details of equipments.

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Annexure B

DETAILS OF TRACTION TRANSFORMER

SN	Parameter	Value
1	Type	LOT-6500 / LOT-7500*/LOT-7775**
2	Original Design	Secheron SA
3	Windings: Traction Auxiliary Filter Hotel Load*	 4 1 1 1*/2**
4	Frequency (f nom)	50 Hz
5	Primary Voltage: Maximum Nominal Minimum	 30.0 kV 25.0 kV 17.5 kV
6	Voltage Ratings (at 25.0 kV Catenary): Traction Auxiliary Filter Hotel Load*	 1269V 1000V 1154V 750V*/960**V
7	Current Ratings: HT Traction Auxiliary Filter Hotel Load*	 311 A 4 x 1142A 334A 347A 1X1260A*/2X648A**
8	Thermal Ratings: Primary Traction Filter Hotel Load*	 6531 kVA 4 x 1449 kVA 400 kVA 945 kVA*/2X622.5kVA**
9	Winding Data: Traction Auxiliary Filter Hotel Load*	 37.0 mΩ, 2.1 mH ± 15% 60.0 mΩ, 0.43 mH 19.0 mΩ, 0.29 mH 11.0 mΩ, 0.37 mH*

* Hotel Load winding available on LOT-7500.

** Hotel Load winding proposed on LOT-7775

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CHARACTERISTICS OF TRACTION MOTORS

SN	Characteristics	Unit	6FXA 7059	6FRA 6068
1	**Continuous Rating**			
.1	Shaft output	KW	1150	850
.2	Nominal Voltage	V	2180	2180
.3	Current	A	370	270
.4	Speed	Rpm	1585	1283
.5	Torque	Nm	6930	6330
.6	Frequency	Hz	80	65
.7	Power Factor	-	0.86	0.88
2	**One Hour Rating**			
.1	Shaft output	KW	1150	850
.2	Nominal Voltage	V	2044	2089
.3	Current	A	396	290
.4	Speed	Rpm	1485	1135
.5	Torque	Nm	7420	7140
.6	Frequency	Hz	75	57.5
.7	Power Factor	-	0.86	0.86
3.	**Short Time Overload Rating:**			
.1	Shaft output	KW	1150	850
.2	Nominal Voltage	V	1540	1660
.3	Current	A	540	370
.4	Speed	Rpm	1107	892
.5	Torque	Nm	9920	9100
.6	Frequency	Hz	56.5	45.7
.7	Power Factor	-	0.85	0.86
4.	Max. Speed	Rpm	3174	2584
5.	Temperature Sensor	2 Pt. 100 resistance elements installed in stator tooth.		
6.	Speed Sensor	Active Hall effect speed sensor with tooth wheel ring for 120/200 pulses per rotor revolution.		

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Annexure C

LOAD ON AUXILIARY CONVERTER

Existing load connections (Revised load distribution with modification release 434):

BUR1 : Both oil cooling units

BUR2 : Both traction motor blowers & all four oil pumps

BUR3 : Both compressors, both scavenge blowers & battery charger

Distribution with Three Converters:

Following are the load distribution. However, IR reserves right to redistribute the load as per its requirement. This shall be finalized during design approval stage. This distribution is for 3x130 kVA concept.

BUR-1		
	Oil cooler blower-1	30 kW
	Oil cooler blower-2	30 kW
	Total	**60 kW**

BUR-2		
	Traction Motor blower-1	25 kW
	Traction Motor blower-2	25 kW
	Oil pump transformer-1	4.7 kW
	Oil pump transformer-2	4.7 kW
	Coolant pump converter-1	2.5 kW
	Coolant pump converter-2	2.5 kW
	Cab AC 1	2 kW
	Cab AC 2	2 kW
	MR Blower 1	2.7 kW
	MR Blower 2	2.7 kW
	Scavenge Blower to MRB 1	0.75 kW
	Scavenge Blower to MRB 2	0.75 kW
	Total	**75.3 kW**

BUR-3		
	TM Scavenge blower-1	3 kW
	TM Scavenge blower-2	3 kW
	Compressor -1	15 kW
	Compressor -2	15 kW
	Battery charger	12 kW
	Total	**48 kW**

When BUR-1 Isolated

BUR-2		
	Traction Motor blower-1	25 kW
	Traction Motor blower-2	25 kW
	Oil cooler blower-1	30 kW
	Oil cooler blower-2	30 kW
	TM Scavenge blower-1	3 kW
	TM Scavenge blower-2	3 kW
	MR Blower 1	2.7 kW
	MR Blower 2	2.7 kW

	Scavenge Blower to MRB 1	0.75 kW
	Scavenge Blower to MRB 2	0.75 kW
	Total	**106 kW**

BUR-3		
	Oil pump transformer-1	4.7 kW
	Oil pump transformer-2	4.7 kW
	Oil pump converter-1	2..5 kW
	Oil pump converter-2	2.5 kW
	Compressor -1	15 kW
	Compressor -2	15 kW
	Battery charger	12 kW
	Total	**73.4 kW**

When BUR-2 ISOLATED

BUR-1		
	Traction Motor blower-1	25 kW
	Traction Motor blower-2	25 kW
	Oil cooler blower-1	30 kW
	Oil cooler blower-2	30 kW
	TM Scavenge blower-1	3 kW
	TM Scavenge blower-2	3 kW
	MR Blower 1	2.7 kW
	MR Blower 2	2.7 kW
	Scavenge Blower to MRB 1	0.75 kW
	Scavenge Blower to MRB 2	0.75 kW
	Total	**106 kW**

BUR-3		
	Oil pump transformer-1	4.7 kW
	Oil pump transformer-2	4.7 kW
	Oil pump converter-1	2.5 kW
	Oil pump converter-2	2.5 kW
	Compressor -1	15 kW
	Compressor -2	15 kW
	Battery charger	12 kW
	Total	**73.4 kW**

When BUR-3 ISOLATED

BUR-1		
	Traction Motor blower-1	25 kW
	Traction Motor blower-2	25 kW
	Oil cooler blower-1	30 kW
	Oil cooler blower-2	30 kW
	Scavenge blower-1	3 kW
	Scavenge blower-2	3 kW
	MR Blower 1	2.7 kW
	MR Blower 2	2.7 kW
	Scavenge Blower to MRB 1	0.75 kW
	Scavenge Blower to MRB 2	0.75 kW
	Total	**106 kW**

BUR-2		
	Oil pump transformer-1	4.7 kW
	Oil pump transformer-2	4.7 kW
	Oil pump converter-1	2.5 kW
	Oil pump converter-2	2.5 kW
	Compressor -1	15 kW
	Compressor -2	15 kW
	Battery charger	12 kVA
	Total	**73.4 kW**

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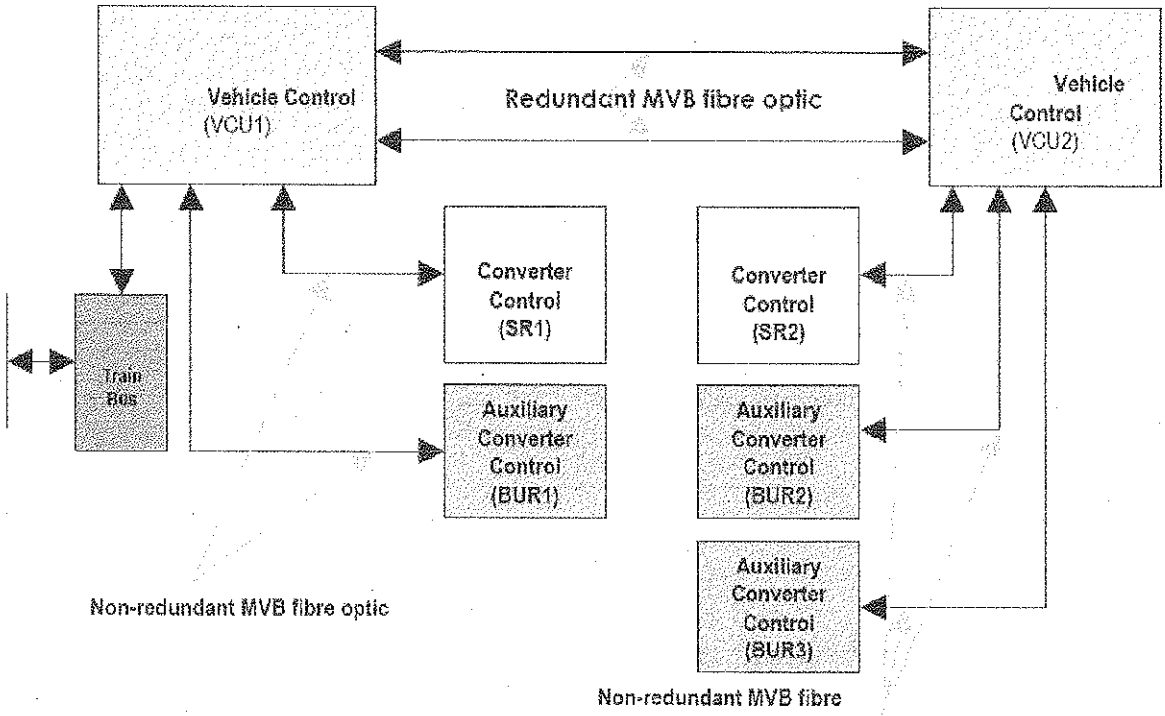
Annexure D

INTERCONNECTION OF VCU WITH TRACTION AND AUXILIARY CONVERTER



Indicative Schematic

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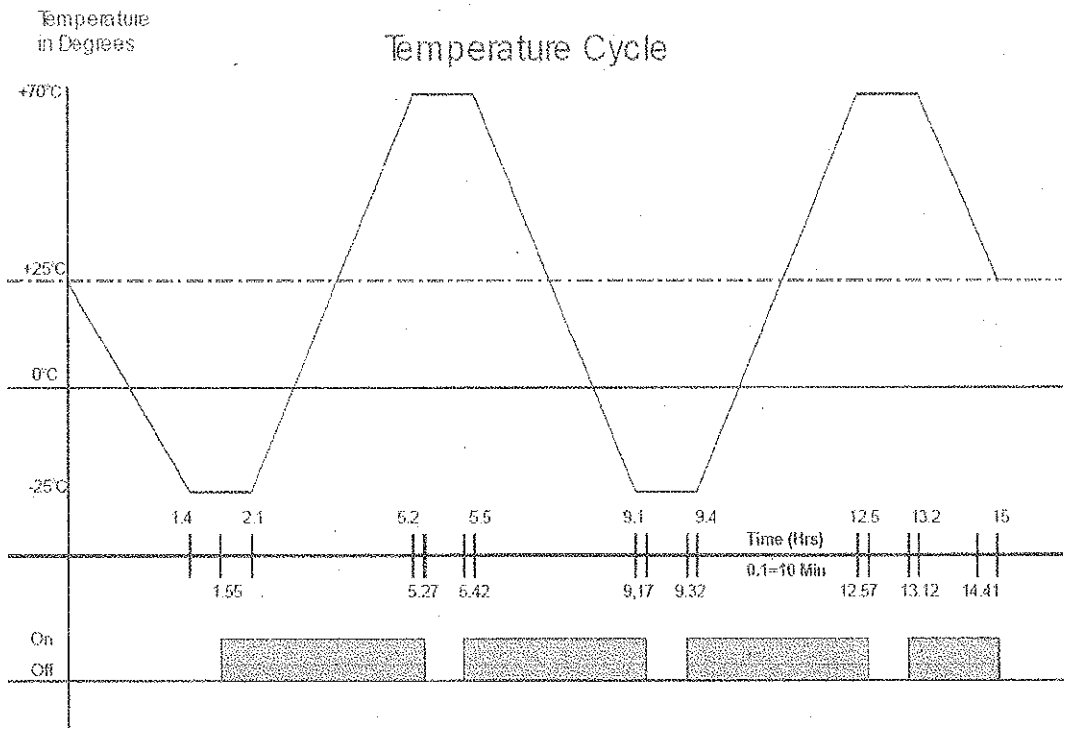
Annexure E

BURN-IN TEST CYCLE



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Annexure F

MODES OF OPERATION AND FUNCTIONALITY OF THE LOCOMOTIVE

1. Modes of Operation (Normal and Degraded)

1.1 Unless stated otherwise in this specification the locomotive provided with IGBT based propulsion equipments in accordance with this specification, shall operate (in normal and degraded conditions) in the same manner as the existing WAG9/WAG9H/WAP7/WAP5 locomotive as described in the current operational manual (Document number 3EHW411172).

1.2 The Supplier shall investigate the operation and functionality of the existing WAG9/WAG9H/WAP7 locomotive and develop the full functionality of the propulsion equipments to provide a similar level of operation.

1.3 For the avoidance of doubt, in addition to meeting the requirements of this specification, it shall be possible for the locomotives, provided with IGBT based propulsion equipments in accordance with this specification, to operate as a single locomotive in the following modes:

(a) Inching Mode - the WAG9 locomotive shall be able to operate at a constant speed settable by the driver in steps of 0.1 Km/h, in the range from 0.5 to 1.5 Km/h with loads up to 6000 tonnes on a gradient of 1 in 1000 or flatter. It shall be possible to change from inching mode to normal mode and vice versa by the driver depending upon his requirement;

(b) Constant Speed Control (CSC) - the locomotive shall be able to operate at a pre-set speed selected by the driver. The selection of speed shall be possible by pressing a switch. However, the system shall be inherently fail safe and shall immediately come out of the pre-set speed mode to normal mode on actuation of the master/ brake controller, reduction of brake pipe pressure, activation of the direct brake or as required from safety considerations; The system must be fail-safe and come out of preset speed mode to normal mode on 'stuck on' of BPCS switch. Speed oscillation at constant speed control must be kept within 3kmph.

(c) Shunting Mode – the locomotive shall be able to shunt the wagons/coaches to create the train formation. This operation shall be the same as that which is undertaken by the existing WAG9/WAG9H/WAP7/WAP5 locomotive.

1.4 It shall be possible to operate a locomotive in multiple with other locomotives of the same type i.e. it shall be possible to operate a Locomotive with other Locomotives. It shall be possible to operate 2 (two) or more locomotives in multiple operation. WTB/DPWCS interface shall be used for interfacing of signals between locos in multiple operation for 2 (two) or more locomotives.

1.5 When operating in multiple the controls of the coupled locomotives shall be achieved from the active cab of the leading locomotive. Provision shall also be made to enable the driver in the active cab to monitor the important parameters of the other locomotives as well as to identify important faults in all locomotives.

1.6 Provision shall be made in the control circuitry of the Locomotive, to limit the starting tractive effort to predefined values when required during multiple operations with other locomotives. The predefined value settings shall be 300 kN per locomotive.

1.7 It shall be possible for the locomotives to operate with other Locomotives in the following modes:

a) trailing mode – the locomotive shall be able to operate the trailing locomotive's traction power from the leading Locomotive's cab, in the event of total failure of the traction power on the lead locomotive;

b) banking mode – the locomotive is mechanically and pneumatically coupled to the rear of a train and the lead locomotive shall control all the train brakes; although in emergencies the rear locomotive driver can activate the emergency brake; and

c) towing mode – following a failure of a locomotive which is prevented from operating under its own power, it shall be possible to haul a Locomotive as part of a train configuration.

2. Functionality of the Locomotive

2.1 Unless stated otherwise in this specification the functionality of the locomotives, provided with IGBT based propulsion equipments in accordance with this specification, shall provide the same operational functionality in normal and degraded conditions, driver controls and interfaces as the existing WAG9/WAG9H/WAP7/WAP5 locomotive as described in the current operational manual (Document number 3EHW411172).

2.2 The following clauses provide an overview of the required functionality of the locomotive. The Supplier shall investigate the operation and functionality of the existing WAG9/WAG9H/WAP7/WAP5 locomotive and develop the full functionality of the propulsion equipments to provide the same level of operation.

2.3 Driving controls and interlocks – the driving controls shall mimic those of the existing WAG9/WAG9H/WAP7/WAP5 locomotive. The system shall have interlocks to prevent tractive effort if the:

a) emergency stop button is active;

b) parking brake, if available, remains applied for speed more than 5 km/h;

c) pneumatic (direct) locomotive brake is applied for speed more than 10 km/h;

d) automatic brake is applied for speed more than 10 km/h;

e) main reservoir is below 5.6 Kg/cm^2;

f) brake pipe pressure is below 4.7 kg/cm^2;

g) isolation cock brake pipe control system is isolated;

h) fire detection system activated; or the

i) emergency exhaust isolating cock is open.

2.4 Traction interlocks – the activation of the traction interlock shall reduce the tractive/braking effort to zero and stop the pulsing of the traction converter. An indicator shall alert the driver to the loss of tractive/braking effort. The following shall activate a traction interlock:

a) vigilance system activation;

b) emergency stop button activation;

c) pressure switch emergency brake;

d) battery voltage too low;

e) 110% over speed;

f) failure of electronic brake control;

g) electric brake failure; and

h) any traction converter failure modes, including angle transmitter disturbance and protective actions where the design process undertaken by the Supplier identifies that a traction interlock is necessary.

2.5 The traction interlock shall be released as soon as the reason for the traction interlock disappears and the driver moves the master controller to the neutral position. This interlock shall be manually released and shall never be an automatic operation.

2.6 Sanding control – this shall be by automatic and manual operation. The manual operation shall be by a foot switch. The automatic operation shall be controlled by the wheel slip/slide control system. Only the leading axles of each bogie shall deliver sand to the wheel rail interface dependent on direction of travel. The sand discharge rate shall optimise adhesion whilst not impeding detection through the track circuits.

2.7 Vigilance – the vigilance system requires the driver to operate, as a minimum, either vigilance foot pedal, the sanding foot pedal, the master controller or the push button provided on the assistant driver's side, within a 60 second period. Any of these actions shall reset the timer. Failure to reset the timer within the 60 second period shall trigger an alarm. The alarm is to be cancelled by the vigilance foot pedal within 16±4 seconds. Failure to cancel the alarm shall activate the emergency brake which shall only be resettable after 32±2 seconds.

2.8 Pantograph control – a mechanical interlock system to ensure that a pantograph cannot be raised until all the HV systems are secured and un-earthed shall be installed. The Locomotive pantograph shall be raised by a selection switch which has three modes and a raise and lower switch which are described below:

a) position "Auto" - automatically selects the pantograph at the opposite end of the locomotive to the activated cab;

b) position "I" - selects the pantograph at the cab 1 end to be raised irrespective of which cab is active; and

c) position "II" - selects the pantograph at the cab 2 end to be raised irrespective of which cab is active.

The selected pantograph shall be raised by the use of an "up" switch. If there is insufficient air pressure to raise the pantograph an auxiliary pantograph compressor shall be automatically activated. The pantograph shall not raise until the auxiliary compressor has de-activated;

The pantograph shall be lowered by the use of a "down" switch. The switch shall open the VCB first, if closed, when activated.

2.9 Compressor Control – the compressors shall be operated in three different modes which are described below:

a) operating mode "Off" - with the switch active in this position both compressors shall be inactive.

b) operating mode "Auto" - with the switch active in this position the compressors shall supply the pneumatic system automatically cutting out once the pressure reaches 10 kg/cm2. The compressor shall automatically reactivate if the main reservoir pressure reduces below 8 kg/cm2. The compressors shall operate simultaneously to ensure that the duty is balanced for both compressors. .

c) operating mode "Man" - with the switch active in this position both compressors shall be active as long as the main circuit breaker is closed. It should be noted that the compressor cut-out switch shall not operate in this position.

2.10 Emergency stop button – there shall be an emergency stop button located on the driver's desk that shall open the VCB, lower the pantograph and apply the emergency brake. The system shall be designed such that the control system shall not reset until the locomotive has come to rest. The button shall be sited such that it is within the reach of the driver but shall not be susceptible to accidental or inadvertent operation.

2.11 Emergency Brake Activation – the emergency brake shall be activated by the following:

a) vigilance equipment exceeding time limits;

b) emergency stop button activation;

c) 110% of maximum speed being exceeded;

d) moving the automatic brake controller to the EMERGENCY position;

e) activation of the emergency brake cock on the assistant driver's side; and

f) failure of the electronic brake control.

2.12 Parking brake control – the parking brake shall be applied and released by the use of a single latch illuminated pushbutton. The parking brake shall be interlocked with the traction equipment to prevent the driver taking traction with the parking brake applied. The drive shall not be able to apply the parking brake if the Locomotive speed is greater than 5 Km/h.

2.13 Control of lighting - the control of the Locomotive lighting shall be similar to that of the existing WAG9/Wag9H/WAP7/WAP5 locomotive. The cab lighting shall be controlled by the driver and all the gauges and meters shall be self-illuminated. The machine room lighting shall be such that all initial fault finding can be undertaken without additional lighting.

2.14 Head lights – the head lights shall have twin beams that are controlled by the driver.

2.15 Marker lights – there shall be two sets of marker lights, one white and one red that are controlled by the driver.

2.16 Flasher light – in the event of the train parting the flasher light shall be automatically activated and any tractive effort on the locomotive shall be disabled until acknowledged by the driver. Similarly, in the event of alarm chain pulling the flasher light shall be automatically activated until acknowledged by the driver. The flasher light shall have the ability to be activated manually by the driver by operating a switch provided on the flasher light unit.

2.17 Battery charger working is very crucial in functioning of the locomotive. When the battery charger is found not working, a popup message is to be generated during every DJ reclosing to alert the crew regarding CHBA not functioning.

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