सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

SPECIFICATIONS AND STANDARDS

FOR

1676 mm GAUGE 7000 kW 6 AXLE

IGBT BASED 3-PHASE DRIVE

ELECTRIC FREIGHT LOCOMOTIVE

Specification No. RDSO/2010/EL/SPEC/0108, Rev.'1'

Approved by	Signature
Sr. EDSE/RDSO	

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ELECTRICAL DIRECTORATE
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4.	-	-	-	-

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Abbreviations

The following abbreviations are used in these Specifications and Standards:

Abbreviation	Full Name
AAR	Association of American Railroad
AC	Alternating Current
AF	Audio Frequency
ATP	Automatic Train Protection
BS	British Standards
CBC	Centre Buffer Coupler
DC	Direct Current
EMC	Electro-magnetic Compatibility
EMI	Electro-magnetic Interference
EN	Euro Norm (European Standard)
EPDM	Ethylene Propylene Diene Monomer
EVA	Ethylene Vinyl Acetate
FEA	Finite Element Analysis
GPS	Global Positioning System
GSM	Global System for Mobile
GSM-R	Global System for Mobile – Railways
HT	High Tension (Voltage) (according to Indian Electricity Rules)
IEC	International Electro technical Commission
IEEE	Institution of Electrical and Electronic Engineers
IGBT	Insulated Gate Bipolar Transistor
IR	Indian Railways
IRS	Indian Railway Standards
IS	Indian Standard
JIS	Japanese Industrial Standards
ISO	International Standards Organization
Kmph	Kilometers per hour

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LED	Light Emitting Diode
MMI	Man-Machine Interface
MSU	Motor Suspension Unit
OHE	Over Head Equipment
RAMS	Reliability, Availability, Maintainability and Safety
RDSO	Research Designs & Standards Organisation
UHF	Ultra High Frequency
UIC	Union Internationale des Chemins de Fer (International Union of Railways)
VHF	Very High Frequency
VCU	Vehicle Control Unit
VCD	Vigilance Control Device

Definitions and Interpretations

The rules of interpretation as specified in Clause 1 (General Provisions) of the General Conditions of Contract shall apply *mutates mutandis* to these Specifications and Standards.

The definitions contained in the Agreement shall apply to the provisions of these Specifications and Standards unless the context otherwise requires. Terms or words not defined in these Specifications and Standards or the Agreement shall be governed by the definitions contained in the standards applicable.

In these Specifications and Standards, the following words and expressions shall, unless repugnant to the context or meaning thereof, have the meaning hereinafter respectively assigned to them:

Term	**Definition**
Agreement	shall mean the 'Contract entered into by Govt. of India for Procurement cum Maintenance of 7000 kW Electric Locomotives.'
BG	shall mean 1676 mm broad gauge used in IR;
BOXN	shall mean the air braked open wagon used by IR;
C&M 1 volume 1	shall mean Civil and Mechanical Engineering Report Number 1 Volume 1, issued by RDSO;
Indian Railways Schedule Of Dimensions	shall mean Indian Railways Schedule of Dimensions for broad gauge, revision 2004;
IP	shall mean degree of protection provided by enclosures according to IEC 60529;
L-10	shall mean life of bearing in accordance with ISO 281;
Man Machine Interface (MMI)	shall mean the interface between the system or equipment and the human interfacing with that equipment;
Ti	shall mean the temperature index of the insulation system;
Others	any capitalized term used herein not specifically defined shall have the meaning ascribed to such term in the Agreement.

References to "**sub-system**" include equipment(s), unless the context otherwise requires. For avoidance of doubt, sub-system does not include consumables, desiccants, lubricants and lubrication system.

Chapter 1

General Description

1.1 Introduction

1.1.1 The Electric Locomotives shall conform to the technical requirements of design, development, manufacture, testing, supply, delivery, commissioning and maintenance of 1676 mm gauge 7000 kW IGBT based 3-phase drive electric locomotives, for use by the Indian Railways as per the Specifications and Standards set forth herein.

1.1.2 The Locomotive shall be configured as Co-Co unit with driver's cab at each end of the Locomotive.

1.1.3 The operating and environmental conditions, performance requirements and technical requirements are specified in these Specifications and Standards.

1.1.3 The design and manufacture of the Locomotive and the various sub-systems thereof shall be based on the requirements set out in these Specifications and Standards and in accordance with Good Industry Practice.

1.1.4 The Company shall demonstrate, to the satisfaction of the Government, that the sub-systems proposed to be used in the Locomotives are based on proven technology and design. For the avoidance of doubt, the Government may require the Company to conduct such tests and trials as may be necessary to establish the reliability and efficiency of such technology and designs in accordance with the Good Industry Practice.

1.1.5 Due consideration shall be given at design stage to ambient conditions of dust, moisture, high temperature and vibrations prevalent in India, as specified in Clause 2.6 of these Specifications and Standards.

1.2 References to various standards

1.2.1 The standards applicable and relevant to the complete Locomotive and to the various systems and sub-systems shall be:

(i) IEC publications;

(ii) EN ;

(iii) UIC;

(iv) AAR

(v) IEEE;

(vi) BS;

(vii) IS;

(viii) JIS; and

(ix) Any other standards referred to in these Specifications and Standards.

In the event of any contradiction in the aforesaid standards, the following standards shall have priority in the order listed:

(i) Standards mentioned in Specifications and Standards set forth herein;

(ii) EN publications/IEC/AAR/UIC/JIS; and

(iii) IS

For avoidance of any doubt, in case of any conflict between the requirements of these standards, the stipulations of these Specifications and Standards shall have precedence.

1.2.2 The design of the Locomotive and the systems and sub-systems thereof shall comply with the following standards:

1.	Electric traction – rolling stock – test methods for electric and thermal /electric rolling stock on completion of construction and before entry into service	:	IEC 61133
2.	Electronic converter fed alternating current motors	:	IEC 60349 –2
3.	Railway application – rolling stock – Part 3: combined testing of alternative current motors fed by an indirect converter and their control system	:	IEC 61377-3
4.	Guide for the evaluation and identification of insulation systems of electrical equipment	:	IEC 60505
5.	Electric railway equipment-train communication network	:	IEC 61375-1

6.	Rotating electrical machines: Functional evaluation of insulation systems	:	IEC 60034-18
7.	Railway applications – electromagnetic compatibility – Part 3-2: rolling stock – Apparatus	:	EN 50121-3-2/ IEC 62236-3-2
8.	Railway applications – electromagnetic compatibility – Part 2: emission of the whole railway system to the outside world	:	EN 50121-2/ IEC 62236-2
9.	Railway applications – compatibility between rolling stock and train detection system	:	EN 50238
10.	Transformer and chokes	:	IEC 60310
11.	Transformer oil	:	IEC 60296/ IS12463
12.	High voltage AC circuit breaker	:	IEC 60056
13.	Rules for pantograph of electric rolling stock	:	IEC: 60494 Pt.I
14.	Relays, contactors and switches	:	IS 3231, IEC, 60947
15.	Cables	:	IEC 60228, IS 10810
16.	Lightning arrestor	:	IEC 60099-4, IS 3070 pt III
17.	Railway applications – rolling stock equipment – shock and vibration test	:	IEC 61373
18.	Programming languages for PLC	:	IEC 61131
19.	Railway applications – electric equipment for rolling stock	:	IEC 60077
20.	Electronic equipment used on rail vehicles	:	IEC 60571
21.	Power converter installed on board rolling stock – Part 1: Characteristics and test methods	:	IEC 61287-1
22.	Power converter installed on board rolling stock– Part 2: Additional technical information	:	IEC 61287-2
23.	Railway application – rolling stock protective provisions against electrical hazards	:	IEC 61991

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24.	Auxiliary machines	:	IEC 60034
25.	Power factor correction	:	IEC 60871
26.	Control cubicle	:	IEC 60068
27.	Batteries	:	IEC 60623
28.	Degree of protection provided by enclosures	:	IEC 60529
29.	Rules for installation of cabling	:	EN 50343
30.	AAR approved couplers and coupler yokes	:	M-211
31.	Wheels	:	IRS R-34
32.	Axle	:	IRS R-43
33.	Railway applications, welding of railway vehicles and components. Inspection, testing and documentation	:	EN15085 / JISZ3420, JISZ321-1, JISZ3801, JISZ3841
34.	Air brakes	:	RDSO's specification No. 02-ABR-02
35.	Schedule of Dimension for broad gauge	:	IR Schedule Of Dimension for Broad Gauge, revision 2004 with latest addendums and corrigendum slips
36.	Reliability of electronic component	:	IEC 61709
37.	RAMS	:	EN 50126/ IEC 62278
38.	Metallised carbon strip for pantograph	:	RDSO's specification no. RDSO/2009/EL/SPEC/0097, Rev'0'

Table 1 - Standards

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1.2.3 The latest version of the aforesaid standards, which have been published at least 60 (sixty) days before the last date of bid submission shall be considered applicable.

1.2.4 Where the aforesaid standards are based on ambient and environmental conditions which are less onerous than those stated in these Standards and Specifications, the conditions stated in these Standards and Specifications shall be applied in the design and testing of the Locomotive and the systems and sub-systems; and the requirements of the aforesaid standards shall be adjusted accordingly.

1.2.5 Alternative Standards

The requirements listed in these Specifications and Standards are the minimum. The Company may adopt alternative internationally recognised codes, standards and specifications if it can demonstrate to the Government that such alternative is superior or more pertinent to the Locomotive than the standards specified in these Specifications and Standards. The Company shall seek the prior approval of the Government for any alternate standards proposed to be used.

1.3 Quality of materials, manufacturing processes and workmanship

1.3.1 All materials (including surface coatings, metals, insulants, adhesives, fluids, grease etc.) used in the construction of the Locomotive shall not give rise to health hazards for crew and staff. The materials shall also be suitable for standard repair operations such as those currently used by the Government (e.g. welding, cutting etc.) without the need for staff to be protected by other than standard means.

1.3.2 Materials shall be suitable for disposal without any special precautions.

1.3.3 Materials used for the Locomotive shall be appropriate for achieving the Design Life of the Locomotive.

1.4 Reliability, Availability, Maintainability and Safety (RAMS)

1.4.1 General

The Company shall design the Locomotive to ensure Guaranteed Reliability, Guaranteed Availability and high degree of safety in order to provide a dependable service. The optimization of the system with respect to Reliability, Availability, maintainability and safety shall form an integral element of these Specifications and Standards

The plan for Reliability, Availability, maintainability and safety shall conform to EN 50126/ IEC 62278. Reliability of electronic components shall conform to IEC 61709.

1.4.2 The Company shall develop RAMS targets both for the complete system and for the major sub-systems such as transformer, traction converter, auxiliary converter, electronics, traction motor, high voltage equipments, blowers and other auxiliary machines, such that it will provide a high level of dependability.

1.4.3 Components critical for safety shall fall into safe operating mode in case of malfunctioning. The system safety plan shall identify and list safety critical components, and this list shall be updated periodically.

1.4.4 The Company shall establish and operate a detailed reliability, availability, maintainability and safety (RAMS) Assessment system in support of the design, manufacture and subsequent testing, commissioning, operation and maintenance of the Locomotives.

1.4.5 Safety Assessment shall be carried out and shall include the following principles:

(i) Degraded modes and emergency operations shall be considered as well as normal operations;

(ii) safety risk assessment shall utilize more than one methodology to assess risks; and

(iii) safety risk assessment shall include the consideration of dependent failures, in particular the traction power, braking and control systems.

1.5 Infringement of Patent Rights

IR shall not be responsible for infringement of patent rights arising due to similarity in design, manufacturing process, use of similar components in the design and development of the Locomotive and any other factor not mentioned herein which may cause such a dispute. The entire responsibility to settle any such disputes/matters lies with the Company.

Chapter 2

Operating and Environmental Conditions

2.1 The Locomotive shall be able to operate and achieve the safety and reliability targets defined in Chapter 3 of these Specifications and Standards whilst satisfying the operating and environmental requirements detailed in this Chapter 2 of these Specifications and Standards.

2.2 Operating Routes

The Locomotive shall be able to operate on under the operating and environmental conditions described in this Chapter 2 of these Specifications and Standards.

2.3 Power supply system

The power supply system adopted is 25 kV, 50 Hz single phase AC with following features:

Nominal supply voltage	22.5 kV (rms), 50 Hz, single phase, AC	
Normal variation in supply voltage	19 kV to 27.5 kV (rms)	
Occasional maximum voltage	31 kV (rms)	
Occasional minimum voltage	17 kV (rms)	
Normal variation in frequency	± 8% (46 to 54 Hz)	
Stagger of the contact wire	± 200mm on straight track Up to ±300mm on curves	
	Normal OHE	High rise OHE
Normal contact wire height in mid span	5.5 m from rail level	7.48 m from rail level
Max. contact wire height	5.8 m from rail level	7.53 m from rail level
Min. contact wire height	4.58 m from rail level	7.37 m from rail level
Neutral Sections	After every 25 to 50 Kms	

Types of Neutral sections	(i) 41 m in length having insulated over lap on both end and neutral wire in between which is not earthed; and
	(ii) Short neutral sections of approximately 4.61 m and 9.6 m length having an insulated portion (of PTFE) on both sides and middle portion of neutral section which is solidly earthed.
Pantograph bounce	Up to 45 ms

Table 2 – Power supply system

Note: The occasional maximum and occasional minimum voltage may persist for 15 minutes.

2. 4 Track parameters

The track parameters shall be the following:

Gauge	Broad Gauge 1676mm
Schedule of dimensions	Indian Railways Schedule of Dimensions for Broad Gauge (1676mm). Revised, 2004
Sharpest curve to be negotiated	175 m radius (horizontal); 4000 m for A route (vertical) 3000 m for B route (vertical) 2500 m for C, D & E routes (vertical)
Sharpest reverse curve to be negotiated	175 m radius (horizontal) back to back with or without any straight portion in between
Sharpest turnout to be negotiated	6400 mm overriding switch (curved) BG (1673 mm) for 60 kg (UIC) or 52 kg rail for 1 in 8½ (crossing angle, tanθ) turnouts on pre stressed concrete sleepers
Maximum Super elevation	165mm for group A, B & C routes 140mm for group D & E routes (in special case, 185mm for A route)
Maximum cant deficiency	100 mm for group A & B and 75 mm for group C, D & E routes
Gauge widening:	
➢ On curves of > 350m radius	-5mm to +3mm
➢ On curves of < 350m radius	Up to +10mm

Permissible Track Tolerances: Peak based tolerances as per Para 607(2) of Indian Railways Permanent Way Manual (Reprinted, 2004)		
Parameter	**Tolerances**	
Gauge The maximum limits for tight and slack gauge should be as per the following (based on Para 224(2) (e))	a) On straight	-6 mm to +6 mm
	b) On curves with radius 350 m or more	-6 mm to +15 mm
	c) On curves with radius less than 350 m	Upto +20 mm
Twist(to be measured on a base of 3.5m)	a) On straight and curve track, other than on transitions-	2mm/metre except that at isolated locations**, this may go upto 3.5 mm/metre.
	b) On transitions of curves	Local defects should not exceed 1 mm/meters, except that at isolated locations** this may go upto 2.1 mm per metre.
Unevenness rail joint depressions (versine measured on a chord of 3.5m)	10mm in general and 15 mm for isolated locations**.	
Alignment(Versine measured on a chord of 7.5 metres under floating conditions)	a) On straight Track- 5 mm; values upto 10mm could be tolerated at few isolated locations**. b) On Curves - ±5 mm over the average versine, Values, Upto ±7 mm could be tolerated at few isolated locations**. Total change of versine from chord to chord should not exceed 10mm.	
(**) In above 'few isolated locations' has been taken as not exceeding 10 per km.		

Table 3 – Track parameters

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Note:
The tolerances mentioned in table above are maintenance tolerances for guidance of maintenance engineers from passenger comfort point of view. These are not safety tolerances and track during course of maintenance may not confirm to these tolerances. The Locomotive may be required to run on a track which is of an inferior standard. These parameters are based on paragraphs 607(1) and 607(2) of Indian Railways Permanent Way Manual.

SD (Standard Deviation) based Track Standards (mm)

		Priority –I	
		Track Standards	
Parameter	**Chord/base(m)**	**Upto 110 Km/h**	**>110≤130 Km/h**
Unevenness	3.6	3.3	3.0
	9.6	7.4	6.2
Twist	3.6	4.2	3.8
	4.8	5.0	4.5
Alignment	7.2	3.8	3.0
	9.6	6.3	4.0
Gauge		3.6	2.6

Table-3A Standard deviations based track standards

Note:

1. The above values are in SD form.
2. The SD of each parameter has been calculated for a block length of 200m.
3. The sampling interval is from 0.25 m to 0.40 m in different TRCs (Track Recording Cars). The SD is calculated from the sampled values collected in 200 m length.
4. Sampled values are collected on specified chord length/base.
5. The above values are for priority level- I, i.e. the blocks having SD values more than above values in various parameters shall be attended on top priority.

2.5 Gauging

The Locomotive with new wheels and any externally mounted equipment shall satisfy the requirements of RDSO drawing number 1D, which is specified in Annex 1 of these Specifications and Standards.

2.6 Climatic and Environmental Conditions

The climatic and environmental conditions prevailing in India in the area of operations are the following:

➢ Atmospheric temperature	Maximum temperature: 50 degree Celsius Maximum touch temperature of metallic surface under the Sun: 75 degree Celsius and in shade: 55 degree celsius Maximum temperature near electronic cards in un-energised condition of locomotive standing under direct sunlight during summer: 70 degree Celsius Maximum temperature near electronic cards in working condition of locomotive during summer: 65 degree Celsius Minimum temperature: - 10 degree celsius (Also snow fall in certain areas during winter season)
➢ Solar radiation	1 kW/m^2
➢ Humidity	100% saturation during rainy season
➢ Altitude	160 m above mean sea level
➢ Rain fall	Very heavy in certain areas.
➢ Atmospheric conditions	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 coal mine areas, the dust concentration is very high affecting the filter and air ventilation system
➢ Coastal area	humid and salt laden atmosphere with maximum pH value of 8.5, sulphate of 7 mg per liter, maximum concentration of chlorine 6 mg per liters and maximum conductivity of 130 micro siemens / cm
➢ Vibration	The vibration and shock levels recorded on various sub-systems in existing locomotives of IR are generally more than the limits given in IEC 61373 particularly at axle box, and traction motor Accelerations over 500 m/s^2 have been recorded at axle box levels during run. Vibrations during wheel slips are of

	even higher magnitude High level of vibrations above 30g have been measured at traction motor on IR's locomotives, which increase up to 50g with worn gear-pinion.
➢ Wind speed	High wind speed in certain areas, with wind pressure reaching 150 kg/m^2

Table 4 – Climatic and environmental conditions

2.7 Signal and Telecommunication Installations

2.7.1 The tracks over which the Locomotive propulsion system shall work may be equipped with AF (Audio Frequency)/ DC track circuits and AC track circuits at 83.33 Hz and at higher frequencies. Similarly, other devices like axle counters, block instruments, point machines, etc., may also be used. On the communication network, control circuits and teleprinter circuits, VHF/UHF and microwave circuits are used.

2.7.2 The harmonic currents injected in the overhead supply system (as also the track return current) can introduce voltage harmonics on power supply and can interfere with signal and telecom circuits. The design of the power electronics and control electronics provided on the propulsion system shall be such as not to cause levels of interference exceeding the levels specified below at any point on the operating routes identified in Clause 2.2 of these Specifications and Standards or on adjacent lines under all modes of operation (including multiple operations) and including failure modes:

SN	Interference Current	Overall Limit
1.0	Psophometric current AC traction	10.0 A
2.0	DC component in AC mode	4.7 A
3.0	Second Harmonic component (100 Hz) and 83.33 Hz component in AC traction	8.5 A
4	1400 Hz up to 5000 Hz	400 mA
5(i)	>5000 Hz up to 32000 Hz	270 mA
5(ii)	39500 Hz up to 43500 Hz	270 mA

Table 5 – Interference current limits

(Note: The measurement of the interference current shall be done in track return current circuit of the Locomotive.)

2.7.3 The Company shall undertake FFT (Fast Fourier Transformation) analysis of the total current from 1000Hz to 5000Hz and 5kHz to 50kHz separately to find out the frequencies which produce the highest currents within each bandwidth. In the frequency bands >32000Hz to <39500Hz and >43500Hz to 50000Hz the frequencies at which the current values exceed 270mA shall be identified. This test shall be included within the tests listed in Clause 5.6 of Particular Specifications of Testing and Commissioning and the results shall be provided in a Type Test report.

2.7.4 EN 50238 is currently under revision and shall include interference current limits for track circuits and axle counters. Where these overall interference current limits are more onerous than those stated in Clause 2.7.2 of these Specifications and Standards these limits shall be applied subject to provisions made in Clause 1.2.3 of these Specifications and Standards.

2.8 EMC

2.8.1 The Locomotives shall comply with the EN 50121/IEC62236 series of Railway Electromagnetic Compatibility standards and EN 50238.

2.8.2 The Company shall prepare, implement and maintain an EMC Management Plan in accordance with the standards referenced in Clause 2.8.1 of these Specifications and Standards. Where the Company requires additional information regarding the operational environment of the Locomotives this shall be listed as part of the Design Package and the Government shall, if available, provide this information within a reasonable time period.

2.9 Train and Locomotive Resistance Data

The train resistance and locomotive resistance data as followed by IR is given below:

i) Train resistance (of BOXN wagon excluding Locomotive)

a) Main starting resistance on level tangent track (including acceleration reserve) = 4.0 (in kg/tonne)

b) Main running resistance on level tangent track = 0.6438797 + 0.01047218 V + 0.00007323 V^2 (in kg/tonne), where V is speed in Kmph

ii) Grade resistance = 1/G x 1000 (in kg/tonne), where G is gradient (e.g. G=200 in case of 1 in 200 gradient)

iii) Curvature resistance = 0.4 x curvature in degree (in kg/tonne)

iv) Locomotive resistance:

a) Starting resistance on level tangent track = 6.0 (in kg/tonne)

b) Running resistance on level tangent track = 0.647 + 13.17/W + 0.00933V + 0.057/WN x V^2 (in kg/tonne)

Where W = Axle load of the Locomotive in tonne

N = Number of Axle

V = Speed in Kmph

Chapter 3

Performance Requirements

3.1 Leading parameters of Locomotive

The performance requirements of the Locomotive shall be governed according to the following leading parameters:

Axle load	22.5 tonnes ± 2% upgradable to 25 tonnes ± 2%
No. of axles	6
Weight	135 tonnes ± 1% upgradable to 150 tonnes ± 1%.
Buffing load	The Locomotive shall be designed to withstand static buffing load of 400 tonnes at the buffers
Lateral forces	The lateral force measured at axle box level shall be <= 4.7 tonnes
Dynamic augment	Dynamic augmentation in vertical direction of load shall be <= 50%
Type of coupler	AAR "E" type coupler head and with AAR "F" type shank and AAR "F" type yoke
Height above rail level of centre buffer coupler (with new wheels)	1090 +15/-5 mm
Minimum clearance of all items except wheel from rail level in fully loaded condition and with fully worn wheels	102 mm
Wheel diameter	1140 mm (in new condition) 1040 mm (in fully worn condition)
Schedule of dimensions	The Locomotive shall confirm to Indian Railways Schedule of Dimensions for Broad Gauge, revision, 2004 with latest addendum and corrigendum slips.
Ride Index	Shall not be greater than 4

Table 6 - Leading parameters

3.2 Traction and Braking Performance

3.2.1 With line voltage of 22.5 kV AC and half worn wheels, the Locomotive shall be capable of following performance:

(i)	Starting tractive effort under dry rail condition (up to speed not less than 10 Kmph.)	Not less than 530 kN with 22.5 tonnes axle load Not less than 589 kN with 25 tonnes axle load
(ii)	Continuous rated speed	60 km/h
(iii)	Maximum operating speed with fully worn wheel	100 km/h, upgradable to 120 km/h*
(iv)	Maximum design speed with fully worn wheel	10 % more than maximum operating speed
(v)	Continuous rated power at rail	Not less than 7.0 MW at all speeds from continuous speed to maximum operating speed
(vi)	Regenerative brake effort	25 % of gross weight of the Locomotive over the speed range of 10 km/h to 65 km/h without sliding, and as close as possible to 25% of gross weight at higher speeds
(vii)	Pneumatic brake effort	7% - 9 % of gross weight of the Locomotive
(viii)	Emergency braking distance (with pneumatic brake only)	600 m maximum with 25 tonnes axle load for light engine from 100 km/h to standstill on level tangent dry track
(ix)	Parking brake	An effective spring actuated and air released parking brake shall be provided. Status of application of parking brake shall be displayed in the active cab, even under the Locomotive un-energized condition. The parking brake shall be capable of holding the Locomotive on 1 in 37 gradient
(x)	Independent Brake holding capability	Capability of holding a 300 tonnes train on 1 in 37 gradient

(xi)	Capability to work in flood water	The Locomotive shall be designed to permit its running at 10 km/h in flood water level of 102 mm above rail level

Table 7 – Traction and braking performance

(* Note: No change in gear ratio is envisaged for the speed up gradation. Any change or modification required in software for the speed up gradation shall not entail any cost to the Government.)

3.2.2 Full power shall be available in the voltage range of 22.5 kV to 27.5 kV and normal range of frequency of power supply according to Clause 2.3 of these Specifications and Standards. Variation of power, if any, in the specified occasional maximum to minimum voltage range shall be specified, however the degraded power at 19 kV shall not be less than 84% of the full power and the Locomotive shall continue to work at occasional minimum and occasional maximum voltages as specified in Clause 2.3 of these Specifications and Standards. There shall be no reduction in the maximum tractive effort in the maximum to minimum voltage and frequency range.

3.2.3 The efficiency of propulsion system, consisting of transformer, power converter (line side converter and drive side inverter) and traction motor, of Locomotive shall not be less than 89 % at full load. The efficiency of propulsion system shall be product of efficiency of transformer, power converter and traction motor, measured at full load. Similarly the efficiency of auxiliary converter (including sine filter) shall not be less than 92% at full load. Efficiency at full load means, efficiency computed from parameters measured at conditions corresponding to full load and governed by IEC 60310 for transformer, IEC 61287-1 for power converter and auxiliary converter; and IEC 60349-2 for traction motor.

3.2.4 In inching mode, at a constant speed settable by the driver in steps of 0.1 Km/h, in the range of 0.5 to 10 Km/h, it shall be possible for the Locomotive to haul loads up to 7500 tonnes on a gradient of 1 in 1000 or flatter.

3.2.5 In shunting mode at speeds up to 15 Km/h it shall be possible for the Locomotive to haul loads up to 7500 tonnes on a gradient of 1 in 1000 or flatter.

3.3 Adhesion requirements

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 at least 40 % adhesion. . The adhesion control system shall be capable of giving high adhesion through a wheel slip control system. The formulae for linking adhesion characteristics with the operating speed shall be submitted as part of Design Package mentioned in Clause 6.17 of Particular Specifications of Transfer of Technology.

3.4 During normal operation, the Locomotive shall be able to start and haul freight trains, in a compensated up gradient of 1:200 at a speed of at least 60 Kmph, weighing 6000 tonnes with 25 tonnes axle load.

3.5 The Company shall submit the load table indicating starting and running capabilities of the Locomotive, in terms of train weight in tonnes, on various gradients as part of Design Package mentioned in Clause 6.17 of Particular Specifications of Transfer of Technology. The table shall also include average speed achievable by the Locomotive for a given length of section with different gradients and train weight in tonnes. The details provided by the Company herein shall be deemed to be a performance requirement of the Locomotives.

3.6 Jerk Rate

The starting tractive effort of the Locomotive shall be applied gradually without producing jerks in the train being hauled by the Locomotive when its application is initiated at zero speed, and it shall be maintained constant throughout the starting process, even if the starting process is considered to have ended when the rated power curve of the Locomotive is achieved. The tractive effort at all other speeds shall also be applied gradually without producing jerks in the train being hauled by the Locomotive.

3.7 Noise

3.7.1 The Products shall limit the interior noise and vibration of the Locomotive.

3.7.2 The noise levels emitted from the equipments shall be as low as possible and the equipments shall be designed to prevent drumming, rattles or vibrations throughout the Design Life of the Locomotive.

3.7.3 The Locomotives shall satisfy the following requirements:

(i) Stationary Locomotive

The noise level inside the cab shall not exceed 68 dB (A) with all auxiliary equipment including cab air conditioner operating at its greatest noise output. The noise level shall be measured in the cab along the center line between 1200 mm and 1600 mm above the floor and at a distance over 600 mm from the end of the cab. The measurement shall be conducted in accordance with ISO 3381.

(ii) Moving Locomotive

The noise level inside the cab, when the Locomotive is running at the maximum speed shall not exceed 75 dB (A) with all auxiliary equipment including cab air conditioner operating. The noise level shall be measured in the cab along the center line between 1200 mm and 1600 mm above the floor and at a distance over 600 mm from the end of the cab. The measurement shall be done according to ISO 3381.

3.7.4 All noise levels listed above are in decibels referred to 20 micro pascals as measured with "A" weighting network of standard Type 1 sound level meter with time weighting F.

3.8 Duty Cycle

3.8.1 Other than when required for Scheduled Maintenance and Unscheduled Maintenance the Locomotive shall be available for operational service 24 hours per day, 365 days per year.

3.8.2 Each Locomotive shall be capable of travelling 300,000 km in service annually without any detrimental effect on the performance of the Locomotive.

3.8.3 At times the Locomotive working in adverse terrain shall be required to negotiate longer periods at lower speeds. The typical duty cycle encountered in operation is outlined below and the Locomotive shall be capable of operating under these conditions. However, at times the Locomotive working in adverse conditions shall be required to negotiate longer periods at much lower speeds and in slippery conditions.

Speed (in km/h)	0-10	10-30	30-60	60-80	80-100
% of total running time of Locomotive	5 %	10 %	20 %	50 %	15 %

Table 8 - Typical Locomotive Duty Cycle

3.9 Design Life

The Locomotives will be required to operate in service for a minimum of 35 years and shall have a design life of 35 years.

3.10 Reliability

3.10.1 The Locomotive shall be designed to achieve a high level of reliability, particularly under the extreme environmental conditions experienced in India.

3.10.2 The Locomotive shall be designed, manufactured and maintained to ensure that each Locomotive shall achieve Reliability in accordance with Clause 17 of Particular Specifications for Maintenance of Locomotives.

3.10.3 No single-point failure of the equipments shall cause the complete failure of the Locomotive 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 Company shall identify and advise the Government 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 Package mentioned in Clause 6.17 of Particular Specifications of Transfer of Technology.

3.10.4 In the event of breakdown of any 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.

3.10.5 Where the system design of the equipments 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.

3.10.6 In the event of the failures of certain equipments described below the following performance levels shall be maintained:

(a) breakdown of the line side converter / drive side converter of any traction converter or electrical failure of any traction motor or failure of traction motor blower:

the traction power of the Locomotive shall only be reduced by $1/6^{th}$ (one sixth);

(b) breakdown of an auxiliary converter:

redundancy in the auxiliary converter(s) shall be provided so that in the event of a failure, the traction capacity of the Locomotive is not degraded;

(c) the control electronics (VCU) shall include redundancy so that a failure shall not affect the traction, braking and safety related control operations;

(d) failure of drive controller unit or power supply of the drive controller unit of a line/drive converter of any traction converter:

the traction power of the Locomotive shall only be reduced by $1/6^{th}$ (one sixth);

(e) failure of gate unit or gate unit power supply of line/drive converter of any traction converter:

the traction power of the Locomotive shall be reduced only by $1/6^{th}$ (one sixth);

(f) failure of the multiple unit coupling:

control of all coupled Locomotives shall be maintained by providing adequate redundancy; and

(g) failure of one speed sensor:

the traction power of the Locomotive shall only be reduced by $1/6^{th}$ (one sixth).

(h) breakdown in the air braking system of a bogie:

it shall be possible to isolate the air brake in the bogie; and

(i) breakdown in the electric control of the automatic air brake:

it shall be substituted by the emergency brake.

3.11 Maintenance targets (exchange times/overhaul periodicities)

The design and construction of the Locomotive shall satisfy the Employer's Requirements Particular Specifications for Maintenance of Locomotives.

3.12 Fire Performance

3.12.1 The Locomotive shall be designed and constructed in accordance with BS6853 Category II or an alternative internationally recognised standard.

3.12.2 A reliable fire detection and alarm system shall be provided. The fire detection system shall be located in the machine room and shall be suitably interfaced with the vehicle control unit to notify the driver of an incident.

3.13 Safety

3.13.1 The Locomotives shall operate safely over the operating routes identified in Clause 2.2 of these Specifications and Standards.

3.13.2 The design and construction of the Locomotive shall not introduce uncontrolled risk to the Government or any other third parties.

3.13.3 The locomotive shall satisfy the Safety Requirements of General Conditions of Contract.

3.13.4 Any of the equipments which are critical for safety shall fail to a safe operating mode.

3.13.5 The risks associated with the Locomotive shall be to a level that is tolerable and as low as reasonably practicable. To demonstrate this, the Company shall apply internationally recognised safety criteria and submit details of these as part of the Design Package.

3.13.6 The Company shall conduct a safety assessment in accordance with the requirements of EN 50126/IEC 62278 to demonstrate that the safety targets and requirements detailed in this Clause 3.13 of these Specifications and Standards.

3.13.7 The Company shall produce all necessary safety documentation to address the requirements of EN 50126-1 and to assist the Government to ensure the safe operation and maintenance of the Locomotives over their entire Design Life.

Chapter 4

Technical requirements

4.1 General

4.1.1 Machine room and cab shall be protected against dust and water in accordance with IP 54 with all doors and windows in closed conditions; and the sub systems inside machine room and cab shall be suitably protected against dust and water. The traction motor shall be protected as per IP 20. The other sub-systems and systems of the Locomotive shall be protected against dust and water as otherwise specified in these Specifications and Standards.

4.1.2 The design and arrangement of the sub-systems and systems shall ensure that the performance requirements of the Locomotive are achieved under the climatic and environmental conditions prevalent in India as specified in Clause 2.6 of these Specifications and Standards. Adequate margin, in accordance with Good Industry Practice, shall be built in the design of the sub-systems and systems of the Locomotive to take care of conditions of high ambient temperatures, dust, humidity, shock and vibration as specified in these Specifications and Standards. The equipment, sub-system and their mounting arrangement shall be designed to withstand satisfactorily the vibrations and shocks encountered in service and as specified in IEC 61373 except where specifically defined in these Specifications and Standards. The under slung equipments shall have sufficiently strong design and shall be suitably protected to withstand ballast hitting encountered while the Locomotive is in operation.

4.1.3 The 'tractive effort-speed' and 'draw bar pull-speed' curves shall be drawn after making suitable correction for derating under ambient conditions as specified in Clause 2.6 of these Specifications and Standards and with half worn wheels.

4.1.4 Necessary precautions in accordance with Good Industry Practice shall be taken to ensure that any electromagnetic interference generated in the machine room does not adversely affect the performance of equipments.

4.1.5 Modular constructions shall be adopted and easy access for inspection and maintenance shall be given special consideration in the design and layout of the Locomotive.

4.1.6 The cooling air for traction motors as well as for the other equipments shall be drawn from outside the Locomotive through filters located in the sidewall or in the roof of the Locomotive. However, the air duct design and filter arrangement on side wall and roof shall have to be such that there is no ingress of water from these locations during rainy season. The location of the air filter shall preferably be high on the side walls and air discharge / purge from the bottom of the Locomotive shall be diffused / deflected so that dust/dirt from the bottom does not get sucked in. The system shall be designed in such a way that the intervals between cleaning of any filter elements shall not be less than six

months. The design shall allow in-situ cleaning of filters with the required maintenance tools.

4.1.7 The machine room shall be adequately pressurized and the filters shall be designed to prevent any dust ingress in the machine room. The filter assembly shall be designed having two stage filters: (a) first stage of cyclonic/inertial filter; and (b) second stage of mesh filter. A suitable dust scavenger system shall also be provided to separate out dust.

4.2 Modes of Operation (Normal and Degraded)

4.2.1 It shall be possible for the Locomotive in the following modes:

a) Inching Mode - the 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 10 Km/h in accordance with Clauses 3.2.4 of these Specifications and Standards. 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 speed control shall work within the limits of maximum traction and braking performance as specified in Clause 3.2.1 of these Specifications and Standards. 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; and

c) Shunting Mode – the Locomotive shall be able to shunt the wagons to create the train formation. This operation shall be in accordance with Clauses 3.2.5 of these Specifications and Standards.

4.2.2 It shall be possible to operate a Locomotive in multiple with other Locomotives of the same type. It shall be possible to operate a maximum of 3 (three) Locomotives in multiple operation.

4.2.3 When operating in multiple the control 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.

4.2.4 Provision shall be made in the control circuitry of the Locomotive, to limit the starting tractive effort to predefined values when required during multiple operation with other Locomotives. The two predefined value settings shall be 300 kN and 353 kN per Locomotive.

4.2.5 It shall be possible for the Locomotive 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.

4.2.6 All the above modes of operation mentioned in this Clause 4.2 of these Specifications and Standards are minimum. The Company may propose any other modes of operation as part of Design package.

4.3 Functionality of the Locomotive

4.3.1 The following Clauses of this Clause 4.3 of these Specifications and Standards provide an overview of the required functionality for the Locomotive.

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

a) emergency stop button is active;

b) parking brake 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.

4.3.3 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 Company identifies that a traction interlock is necessary.

4.3.4 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.

4.3.5 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.

4.3.6 Vigilance – the vigilance system requires the driver to operate, as a minimum, either the 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 120 seconds;.

4.3.7 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.

4.3.8 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 all 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 alternately 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.

4.3.9 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.

4.3.10 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.

4.3.11 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 driver shall not be able to apply the parking brake if the Locomotive speed is greater than 5 Km/h.

4.3.12 Control of lighting - the control of the Locomotive lighting shall be similar to that of the Existing WAG9 Locomotive and Existing WAP7 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 by the driver without additional lighting.

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

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

4.3.15 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. The flasher light shall have the ability to be activated manually by the driver by operating a switch provided on the flasher light unit.

4.3.16 All the above functionalities of the Locomotive mentioned in this Clause 4.3 of these Specifications and Standards are minimum. The Company may propose any other functionalities of the Locomotive as part of Design package.

4. 4 Electrical

4.4.1 Pantographs

4.4.1.1 The Locomotive shall be equipped with two pantographs. The pantograph selector switch shall be provided in the driver's cab for raising the pantographs in accordance with Clause 4.3.7 of these Specifications and Standards. The raising or lowering of the pantograph, with the Locomotive in motion, shall not cause any undue disturbance to OHE.

4.4.1.2 It shall be possible for each of these pantographs to be electrically disconnected from the roof equipment and earthed in case of damage.

4.4.1.3 The profile of the pantograph shall be in accordance with the drawing no. SKEL-3871 enclosed as Annex 3. Metalised carbon strip complying with RDSO's specification no. RDSO/2009/EL/SPEC/0097, Rev'0' shall be used on the pantograph.

4.4.1.4 The pantograph shall be air operated type and suitable to work in areas having high wind pressure as specified in Clause 2.6 of these Specifications and Standards. The pantograph shall also be suitable to work both in normal OHE and high rise OHE areas having height range as specified in Clause 2.3 of these Specifications and Standards.

4.4.1.5 In static condition, the pantograph shall exert upward force of 7 ± 0.4 kg on OHE.

4.4.1.6 The power drawn by the pantograph of the Locomotive from OHE shall be at a power factor of 0.98 (or better) for power demands above 2MW across the OHE voltage range from 19 kV to 27.5 kV, subject to the interference levels as specified in Clause 2.7 of these Specifications and Standards.

4.4.1.7 Pantograph bouncing as detailed in Clause 2.3 of these Specifications and Standards shall not adversely affect the performance of propulsion equipment.

4.4.1.8 The current drawn by the Locomotive shall be limited such that there shall be no adverse effect on the pantograph or the OHE whilst the Locomotive is at standstill.

4.4.2 Main circuit breakers

Main circuit breaker of proven design shall be provided.

4.4.3 Lightning arrestor

Two metal oxide gapless lightning arrestor (one before main circuit breaker and one after main circuit breaker), in accordance with Good Industry Practice, shall be provided on the roof of the Locomotive for protection against the line voltage transients caused by lightning and system switching.

4.4.4 Main transformer

4.4.4.1 Fixed ratio main transformer shall be provided with multi-traction windings suiting the requirements of power converter, and with auxiliary winding(s) for the auxiliary system.

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

4.4.4.3 The transformer shall be designed with adequate overload capacity, in accordance with Good Industry Practice, to permit full utilization of the traction motor capacity during starting as well as running.

4.4.4.4 The transformer shall be designed to conform to IEC: 60310 and the temperature rise limits on the windings and the oil shall correspond to IEC: 60310 limit minus 20 degree celsius under all conditions of operation.

4.4.4.5 The transformer shall be oil immersed and forced oil cooled by means of an oil circulating pump and a radiator. The radiator shall be air blast cooled by means of a motor driven blower set. Means shall be provided for letting out the oil from the transformer through the floor to the underside of the Locomotive, in the event of any fault/electrical disturbance in the transformer causing oil to rush out. The radiator shall be so designed so that cleaning interval is in synchronization with the Scheduled Maintenance but shall not be less than six months in any case.

4.4.4.6 The transformer tank, radiators and associate equipment shall be coated with pollution/oil resistant and dust repellant epoxy paint.

4.4.4.7 High voltage cable assembly:

High voltage cable assembly, from the Locomotive roof to transformer of adequate size having interface with transformer bushing at the transformer end and with cable head termination bushing fitted at the Locomotive roof, shall be provided in accordance with the Good Industry Practice

4.4.5 Power converter

4.4.5.1 The power converter shall be completely IGBT based, The voltage rating of IGBT shall be higher than the surge voltage across IGBT terminals through main transformer windings, and shall be so chosen that at least 25% margin is available after taking into consideration the DC link voltage and voltage jump on account of inductances and capacitances in the circuit. Water cooling or forced air cooling shall be adopted for power converter IGBT based system.

The current rating of power devices shall be such that the junction temperature has a minimum thermal margin of 10 degree Celsius, at maximum loading conditions under the specified ambient temperature, with respect to maximum permissible junction temperature of power devices declared by the manufacturer.

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 10ºC (degree Celsius) shall be kept with respect to maximum permissible junction temperature of power devices declared by the manufacturer.

4.4.5.2 The protection scheme of the converter and inverter system shall prevent any damage to the converter and inverter system in the event of short circuit current flowing under fault conditions, in accordance with Good Industry Practice. The converter and inverter system shall also be designed to withstand extreme disturbances like short-circuit / open circuit at all points of input / output interfaces with Locomotive, with minimised effects/damages. This shall be Type Tested according to the relevant provisions of the IEC 61287.

Adequate protections not limited to following shall be provided in the converter:

- Over current;
- line or DC link over voltage and under voltage;
- over temperature;
- traction motor over load, over temperature and over speed;
- incorrect connections of traction motor cable (i.e., incorrect phase sequence);
- open traction motor phase;
- earth fault; and
- failure of line/precharging contactors(s) to open when commanded.

4.4.5.3 During the earth fault or phase to phase fault in the traction motor, protection scheme of the power converter shall prevent any damage to the power converter.

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

(i) Independent line converter per axle and independent drive converter per axle with an independent isolating switch at the output of the transformer secondary, for isolating each line side converter-drive side converter segment;

(ii) suitable redundancy in the vital PCBs connected with safety, so that the Locomotive failure and degradation in performance is minimised in the event of their failure;

(iii) the drive controller unit of each line side converter – drive side inverter segment shall be independent and individual;

(iv) the power supply for each drive controller unit shall be independent from any others fitted; and

(v) only dry type capacitors (having self healing property) shall be used for DC link / harmonic filter / resonant circuits.

4.4.5.5 The motor converter output current ripple shall be so maintained that it can keep the torque pulsations and traction motor heating to a minimum. Software based technique shall be adopted instead of hardware control for controlling DC link and torque pulsations of traction motor.

4.4.6 Traction motor and drive

4.4.6.1 The traction motor shall be designed for climatic and environmental conditions as specified in Clause 2.6 of these Specifications and Standards

4.4.6.2 The traction motor shall be suitably rated according to the Locomotive performance requirements for the 'most severe normal service' as defined in clause 8.2.2 of IEC 60077-1.

4.4.6.3 The traction motor shall be axle hung nose suspended. The mechanical design of traction motor, its mounting arrangement on the bogies, transmission system (pinions and gears, gear case, etc.) shall be designed considering the value of shock and vibration in accordance with Clause 2.6 of these Specifications and standards. Various components of traction motors shall be manufactured with such tolerances so as to enable complete interchangeability of components from one motor to another of same design.

Stator winding overhangs shall be suitably supported to the stator frame and rotor design shall take care torsional vibration, thermal and centrifugal stresses encountered during actual service conditions. Material of rotor bars shall be able to maintain its property over the complete operating range of temperature and have high fatigue strength.

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

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

4.4.6.6 The motor shall be designed such that the hot spot temperature under any condition of loading in winding does not exceed the average temperature of that winding measured by resistance method, by more than 15 degree celsius.

4.4.6.7 Insulation system

(i) The insulation system to be employed shall be particularly designed to withstand the adverse climatic and environmental conditions specified in these Specifications and Standards. Imperviousness to moisture shall be ensured.

(ii) the evaluation of the insulation system for thermal endurance shall be with fabricated test models by way of accelerated ageing tests based on the test programme drawn up

in accordance with the norms specified in IEC: 60034-18. Evaluation of the insulation system shall be done according to IEC 60034-18.

(iii) ageing parameters of heat, vibration, mechanical/compressive stresses, special environmental effects of humidity, dust and metallic dust from brake shoes shall be incorporated to simulate the actual working conditions as closely as possible.

(v) the temperature at which an extrapolated life of 20,000 hours is obtained shall be treated as the thermal endurance limit (Temperature Index) of the insulation system.

(vi) with regard to the system of insulation adopted and the climatic and environmental conditions, the Company shall provide maximum possible margins in the temperature rise, for prolonged life of the traction motors.

4.4.6.8 Maximum temperature rise of traction motor winding shall be limited to Ti – 70 degree celsius, considering 25% choking of filters. Thermal simulation of temperature rise in stator and rotor with given duty cycle of the locomotive operation shall be carried out to establish maximum temperature rise shall be within Ti – 70. The simulation result shall be provided as part of Design Package. The temperature rise in stator and rotor winding shall be validated through physical measurement on traction motors during the Type Tests.

4.4.6.9 Maximum design speed of the traction motor at the highest working speed shall be less than 3000 revolutions per minute.

4.4.6.10 The following operational and environmental factors shall also be kept in view in the design of the motor:

(i) Prevalence of high temperature and humidity and highly dusty environments for most part of the year; and

(ii) operation of the Locomotive over a long country terrain in which the climate shall vary from excessive dry heat on one end to high humidity on the other end or during winter months from very cold conditions at one end to moderately warm and humid conditions at the other.

4.4.6.11 Harmonic/Ripple factor

The traction motor shall operate satisfactorily over the entire range of loading, with harmonic/ripples imposed on from the IGBT based supply system (comprising of the transformer and power converter both during motoring and regeneration braking conditions).

With the harmonics/ripples generated by the power converter, temperature rise in traction motor shall be in accordance with that mentioned in Clauses 4.4.6.6 and 4.4.6.8 of these Specifications and Standards.

With regard to the system of insulation adopted and the climatic and environmental conditions, the Company shall provide maximum margins in the temperature rise, for the prolonged life of the traction motors.

The Company shall conduct necessary tests during Type Tests on the traction motor to establish compliance with this requirement.

4.4.6.12 Traction Motor Drive

The torque transmission arrangement from traction motor to axle shall be simple and suitable for both traction and braking forces. The tractive/braking effort shall be directly transferred from the traction motor pinion to the wheel gear. The design of traction motor drive for each axle shall also take into account the change caused in axle loads on account of weight transfers produced by traction or braking effort during powering and braking. Lubrication system for gear/pinion shall be kept physically segregated from traction motor bearings and motor suspension unit bearings. Both the ends (drive and non-drive) of traction motor and motor suspension unit bearings shall be grease lubricated, only. The complete arrangement shall be of proven design for same or higher traction/braking torque transmission. However, special care shall be taken in design with respect to high track vibrations in accordance with Clause 2.6 of these Specifications and Standards. The company shall submit relevant details in this regard along with the special measures taken in view of the specified track data and environmental conditions as part of Design Package.

4.4.6.13 Traction Motor Bearings

Criteria of selection of the traction motor bearings (equivalent dynamic and static loading of the system with respect to those of bearings, limiting speed, reference speed, etc.) and its lubrication system (thermal stability) shall be brought out and all the calculations shall be provided as part of Design Package.

The designed L10 life should be at least 1.2 million Kms. If the insulated bearing is used, then the reason for the same shall be specified in the Design Package. For calculation of L-10 life, calculation of equivalent dynamic loading for the proposed traction motor bearing shall be provided as part of Design Package.

Traction motor bearings shall be grease lubricated on both driving end and non driving end sides, independent from gear case lubricants. No intermixing of traction motor bearing lubrication and gear case lubricants shall be done. The greasing interval and overhauling frequency of the bearing shall be specified in Design Package.

Standard and proven bearings with at least one year successful service experience in axle hung nose suspended arrangement shall only be used.

4.4.6.14 Roller Suspension Bearing

The traction motor shall be axle hung nose suspended and with roller suspension bearing. The bearing shall be selected to have L-10 life of 2.5 million Kms. For calculation of L-10 life, calculation of equivalent dynamic loading for the proposed motor suspension unit bearing shall be provided as part of Design Package.

Criteria of selection of the motor suspension unit bearings (equivalent dynamic and static loading of the system with respect to bearings, limiting speed, reference speed, etc.) and its lubrication system (thermal stability) shall be brought out and all the calculations shall be provided as part of Design Package.

Motor suspension unit bearings shall be grease lubricated on both driving end and non driving end sides, independent from gear case lubricants. The design of suspension shall ensure no leakage or ingress of gear case lubrication into the roller bearing under any circumstances. Standard and proven bearings with at least one year successful service experience in axle hung nose suspended arrangement shall only be used.

Details for the interference fit of bearings shall be furnished as part of Design Package. The suitability of the entire drive consisting of traction motor, gear and suspension including axle shall be furnished as part of Design Package along with necessary analysis.

4.4.6.15 Type Tests and Routine Tests on the traction motor shall be in accordance with IEC 60349-2.

4.4.6.16 The lubricant shall be so chosen that the viscosity of the lubricant is not lost even at highest temperature during operation. Temperature rise of the gear box shall be in the range of 30 degree celsius above the ambient temperature.

4.4.6.17 FEA on stators, rotor complete, shaft, bearing cage assembly shall be furnished along with boundary conditions as part of Design Package. Boundary conditions for FEA shall be finalized in consultation with RDSO and vibration level recorded on Indian tracks.

4.4.7 Auxiliary system

4.4.7.1 The auxiliary system shall consist of auxiliary converters, auxiliary machines, blower-motors, compressor motors, oil / water pumps, cab air-conditioner, battery charger, DC loads and associated protection system. The AC auxiliary system shall be galvanically isolated from the traction power system and the DC battery 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 (vector sum of three phases) with respect to earth shall be as low as possible, preferably zero.

4.4.7.2 The auxiliary converters shall be completely IGBT based and forced water cooled or air cooled.

The voltage rating of IGBT shall be higher than the surge voltage across the IGBT terminals through main transformer auxiliary winding. It shall be so chosen that at least

25% margin is available after taking into consideration the DC link voltage and voltage jump on account of inductances and capacitances in the circuit.

The current rating of power devices shall be such that the junction temperature has a minimum thermal margin of 10 degree Celsius, at maximum loading conditions under the specified ambient temperature, with respect to maximum permissible junction temperature of power devices declared by the manufacturer.

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 10ºC (degree Celsius) shall be kept with respect to maximum permissible junction temperature of power devices declared by the manufacturer.

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. Total harmonic distortion at the output voltage shall be less than 10 % and supply regulated to ± 5% of the nominal voltage under all operating conditions.

4.4.7.3 Auxiliary converters of adequate capacity identical in all respects and a battery-charging unit shall be provided in the Locomotive. Design and rating of auxiliary converter and load distribution shall be such that in case one auxiliary converter fails, the remaining shall take the entire auxiliary load and the Locomotive remains healthy. The changeover arrangement shall be automatic.

4.4.7.4 Rating of the auxiliary converters shall be decided after considering the connected loads, requirement of redundancy and keeping a margin of 10 kVA per converter for possible increase of load in future.

4.4.7.5 In addition to above, galvanically isolated 230 V AC, single phase supply of 1 kVA shall also be made available in the driving cabs to enable powering any small equipment when the Locomotive is standing in the shed.

4.4.7.6 In order to reduce energy consumption as well as to increase equipment life, multiple level ventilation control shall be adopted, which shall vary the output of all the blowers according to the cooling needs. Auxiliary converter output and control system shall be designed accordingly.

4.4.7.7 The temperature rise limits for auxiliary machines shall be reduced compared to IEC limits to take care of the higher ambient temperature specified. Insulation system of class 180 degree celsius or higher shall be adopted. The maximum temperature rise shall not be more than 80 degree celsius.

4.4.7.8 Motors for auxiliary machines shall generally be interchangeable. Coupling and mounting design requirements shall be kept identical where applicable. The motors shall be rated for

415 V 3-phase AC supply except for the auxiliary compressor motor which is to be rated at 110V DC.

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

4.4.7.10 Vacuum pressure impregnation of the stator winding shall be done using solventless varnish having thermal index above 200 degree celsius.

4.4.7.11 For motors higher than 15 kW, flange bearing housing units shall be used. The bearing design shall be such that no greasing and no intermediate attention shall be required for at least 18 months.

4.4.7.12 L-10 life of bearings when calculated according to ISO Recommendation R-281 shall not be less than 35000 working hours.

4.4.7.13 Auxiliary compressor set

A 110 volts DC battery operated auxiliary compressor set having sufficient capacity shall be provided for feeding the auxiliary air reservoir for operation of the pantograph and vacuum circuit breaker, during the preparation of the Locomotive for service. A suitable pressure governor device shall also be included.

4.4.7.14 Battery and battery charger

(i) An automatic static battery charger fed from three phase auxiliary supply shall be provided. Its rating and closed loop charging characteristics shall be matched to the battery, by separate monitoring of charging current and voltage and shall have a provision for fine adjustment and good stability to avoid overcharging or undercharging of batteries;

(ii) low maintenance batteries of adequate capacity (C5 capacity) shall be provided on the Locomotive to feed the equipment for at least 5 hours in the event of a failure in the battery charging system. Nominal voltage of the control circuit shall be 110 V; and

(iii) the design and control of the battery shall ensure that the battery gets disconnected from non essential loads when the battery gets discharged, however there shall be sufficient capacity left under all conditions to raise pantograph and to power voice recorder and flasher light. When auxiliary load is reconnected, the initial battery load shall not cause the battery output to oscillate.

4.4.8 Electronics

4.4.8.1 The general provisions of this paragraph shall be applicable to all electronics used, including for power, auxiliary converters and VCU. The electronics used on the Locomotive shall conform to IEC-60571. However, due to higher ambient temperature specified, 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 1.1.5 of this Specifications and Standards). There shall be no requirement of pre-cooling of the electronics on Locomotive standing in sun for long duration. The electronic control equipments shall be protected against unavoidable EMI / EMC in the machine compartment.

4.4.8.2 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. The electronics shall be designed with adequate margin so that there are no failures on thermal account.

4.4.8.3 The electronic cards and couplers / connectors shall be polarized or suitably designed to ensure that insertion in wrong position is not possible.

4.4.8.4 Capacitors shall be suitably rated, keeping in view the high ambient temperature specified, vibrations of electric rolling stock and electrical surges expected during operation. High failure rates of electrolytic capacitors mounted on PCBs of electronic cards are expected due to high operating temperature / voltage / current vis-à-vis designed operating temperature / voltage / current. Dry type of capacitors shall preferably be used. The Expected life of the cards, and electronics in general shall be at least 18 years under actual working conditions.

4.4.8.5 Features of the electronic systems

(i) The diagnostic computer in the Locomotive shall be able to differentiate between fault in rest of the Locomotive and fault in the electronic equipment;

(ii) should the fault be found on electronic equipment, the diagnostic computer shall enable fault finding to be carried out at module level; and

(iii) off-Locomotive test equipment shall be used in the Maintenance Depot. This equipment shall allow fault finding down to the smallest replaceable item of the sub-system.

4.4.8.6 The cooling arrangement of the electronics of the power converter, auxiliary converter and the VCU shall be designed so that the temperature adjacent to the electronic cards remain below 45 ºC (degrees Celsius) while the Locomotive is operating. The cooling of electronics may be combined with cab air conditioning to achieve this, if required. 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.

4.4.8.7 The electronics of the power converter, auxiliary converter and the VCU shall preferably not be placed near to the roof to avoid the effect of solar gain. The electronics shall preferably be placed in a separate compartment away from the converters.

4.4.9 Vehicle Control

4.4.9.1 Control and communication shall be as per IEC 61375 "Train Communication Network" protocol; or ANSI/ATA878.1 "ARCNET" for the train bus and ISO/IEC 13239 & IEC/ISO 842 for local bus; or any other equivalent, internationally published protocol.

4.4.9.2 The majority of the control and monitoring functions shall preferably be implemented by software so as to reduce hardware and cables. The safety integrity level for this software and the associated electronics shall be allocated and assessed in accordance with EN 50126 and the associated international standards.

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

4.4.9.4 Features of self-check, calibration and plausibility check shall be incorporated in the design.

4.4.9.5 The VCU shall interface (including hard wiring) with the brake system. Provision shall also be made to interface with the brake system through multiplexed pairs of wires using an RS-485 protocol. The interface hardware and software shall be designed accordingly.

4.4.9.6 The adhesion control system shall be optimised for maximum utilisation of adhesion factor and shall be capable of generating the required starting tractive effort as detailed in Clause 3.2 of these Specifications and Standards under dry rail conditions. The wheel slip detection and correction system shall be an integral part of the control system and if necessary also of the power converters which shall capture any excessive acceleration, differential speeds between axles, over speed and any other parameter considered necessary to maximise adhesion and minimise wheel slipping / sliding.

4.4.9.7 The VCU shall control the automatic flasher operation (in case of train parting) and the vigilance functionality.

4.4.9.8 The energy metering (energy consumption and energy regeneration) function shall be integrated into the control software and shall provide an accuracy of 5%.

4.4.9.9 The VCU shall have a diagnostics computer, with non-volatile memory, to store all the relevant diagnostic data. On occurrence of each fault, besides the fault information on equipment parameters, background data with time stamp along with GPS data shall also be captured and stored with a view to enable proper fault analysis. There shall be a 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 the faults of the Locomotive on account of wrong operation by the driver 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, shall be displayed in simple language along with background information. Such software shall be compatible for working on commercially available operating systems.

4.4.9.10 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. The fault display to the driver shall be accompanied by the standard trouble shooting instructions in simple English language.

4.4.9.11 A hand held, off line, electronic device shall be provided for trouble shooting / rectification of a fault by the crew. The device shall be portable and easy to carry with feature of pictorial identification of respective equipments of the Locomotive.

4.4.9.12 For diagnostic purposes (including downloads) it shall be possible to access all the processors of propulsion equipments within a Locomotive and other Locomotives in a train formation over a wired train bus using a standard laptop connected to one of the ports provided on the VCU rack. The wired train bus shall satisfy the requirements of IEC 61375 or any other equivalent internationally published protocol. The required interfaces shall be built into the VCU so that standard laptops, with commercially available operating systems, can be used without any special interface. A suitable software tool shall also be provided in the laptops. Using this tool, it shall be possible to reset the diagnostic memory for further recording and undertake detailed analysis off line.

4.4.9.13 It shall be possible for the Government to execute parametric changes (within permissible ranges) in the vehicle control software, if so required in the future, in order to improve the operation of the Locomotive. It shall be possible to configure these parameters through a laptop and a menu-driven, easy to use, application software shall be provided for this purpose. Password protection shall be provided to safeguard against misuse. As a minimum, the parameters to be changed shall be the current and voltage sensor settings, horse power, temperature sensor setting, pressure sensor setting, maximum speed of the Locomotive, wheel diameter, main reservoir pressure setting for loading and unloading of compressor, vigilance control timer settings and maximum tractive effort. It shall be preferable for the Government to have the ability to change further parameters and the Company shall provide details of these as part of the Design Package.

4.4.9.14 The Locomotive shall be provided with remote diagnostic and tracking equipment. The equipment shall be based on GPS, GSM and GSM-R technologies. This equipment shall perform the function of tracking the Locomotive, communicating with the locomotive diagnostic system, and transmitting data to a remote central server. The central server shall be provided by the Company at a place to be nominated by the Government. It shall be possible to remotely obtain the information stored in the diagnostic memory of the onboard computer system with the aim of facilitating and speeding up the maintenance process of the Locomotives.

4.4.10 Synchronous Control System

4.4.10.1 The Locomotive shall be provided with synchronous control system utilising wireless signals between the Locomotives in a train formation; whether at the front, in the middle or at the rear end of train formation. The synchronous control system shall enable all the control and operating signals from the lead Locomotive to be transmitted to the distributed trailing Locomotive(s) through a radio transceiver, so that they are run 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 trailing locomotives for security purposes. The display shall indicate the status feedbacks received from the trailing units. At any time, it shall be possible to view the status of all trailing Locomotive(s) from the leading Locomotive. It shall be possible to use any Locomotive fitted with this system in a leading or trailing or in middle position.

4.4.11 Control equipment

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

4.4.11.2 The control equipments, relays and switches, and such other devices shall be in accordance with the Good Industry Practice.

4.4.11.3 All vital contacts of control circuit for operation of the Locomotive shall be duplicated to provide redundancy.

4.4.11.4 Interlocks and auxiliary contacts of relays of protective, operation, control, auxiliary and safety circuits shall be housed in dustproof enclosures either by providing the complete equipment in dust-proof cabinets and/or pressurising the cabinets or by covering the contacts only by dust-proof covers.

4.4.11.5 The working of all relays and contactors shall be in the range –30 % / +25 % of nominal battery voltage when the operating coils are at their rated temperature and the contacts are subjected to normal pressure.

4.4.11.6 Rubber components, such as pistons, 'O' rings etc. wherever employed in the control gear, brake system and their controls shall be suitable for the specified humid and environmentally severe conditions. The life of rubber components shall not be less than six years.

4.4.11.7 Surge suppression circuits shall be incorporated to eliminate surges, wherever required.

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

4.4.11.9 Endurance tests, both mechanical and electrical, shall be in accordance with IEC 60947-5-1.

4.4.12 Master controller

4.4.12.1 A master controller shall be provided in each cab. It shall be integrated with step less traction / braking lever, forward/reverse switch, etc. In the design of the driver's controls, the following features shall be incorporated:

(i) Master controller to be operational only after operation of cab activation switch;

(ii) it shall not be possible for unauthorized persons to operate the master controller;

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

(iv) interlocks with braking system shall be incorporated in the master controller;

(v) only one cab shall be activated in the Locomotive at a time; and

(vi) provision shall be made to ensure operation of the Locomotive in the event of failure of master controller.

4.4.12.2 The Company shall ensure that the master controller shall not require maintenance earlier than the Locomotive's Biennial Schedule.

4.4.13 Instruments and gauges

OHE line voltage, battery voltage, tractive/braking efforts, energy consumed / regenerated, pressures in the main reservoir pipe, brake actuators, brake pipe and feed

pipe and indication of air flow in the brake pipe and any other indication considered important / relevant for the driver shall be displayed on both the driver's consoles.

4.4.14 Wiring and cabling

4.4.14.1 The cables for wiring in the Locomotives and equipments shall use high grade electrolytic copper stranded conductors tinned in accordance with Good Industry Practice.

4.4.14.2 Electron beam, irradiated, thin walled, halogen free, low smoke and less toxic cables according to relevant international standards and the Good Industry Practice for rolling stock application, shall be used. The insulation/sheathing material shall be EPDM/EVA and shall be fire survival type according to EN 50264. At locations in the Locomotive, where high temperatures are likely to be encountered, special cables shall be used.

4.4.14.3 The layout of the cables shall be such that there is no contamination by oil. Length of power cables shall be kept to minimum. Cables and connections carrying different types of voltages shall be physically segregated from each other. For vital circuits, adequate numbers of spare control wires shall be provided with clear identification. Cable layout shall be according to EN50343.

4.4.14.4 Loading of power cables shall be such that in no case conductor temperature shall exceed maximum temperature according to data sheet minus 10 degree celsius. The power cable layout shall ensure equal sharing of current in all power cables. Derating of cables due to bunching effect and cable layout shall be taken into account during design

4.4.14.5 All connections shall be terminated on terminal bars manufactured in accordance with Good Industry Practice. The terminals and wire cable ends shall be suitably marked to facilitate correct connections.

4.4.14.6 Plugs/couplers and sockets shall be used to connect pre-assembled units to facilitate maintenance and ensure a better layout.

4.4.14.7 No cable having a conductor size of less than 2.5 sq. mm shall be used except for multi core cables where 1.0 sq. mm cable is permitted. Smaller size cables for internal wiring of panels, control cubicles, consistent with the mechanical and electrical requirements, may be adopted.

4.4.15 Lighting

4.4.15.1 The lighting equipment (head light, cab lights, reading lights, corridor lights, marker lights, flasher lights, gauges and instrument lamps to illuminate the dials etc.) shall be based on 110V DC battery supply. The design shall be such that the performance and life of the lamp does not get affected due to variations in battery voltage. Gauges and meters shall be fitted with self-illuminating lights, preferably light-emitting diodes.

4.4.11.5.2 Head Lights

Twin beam head lights shall be provided at each end, working on 110 V halogen lamps having two filaments. Headlight units shall be pre-focused, capable of giving 4.4 lux at a distance of 305 meters. The design shall provide for easy replacement of bulb. Arrangement shall be made for dimming the headlight output when required. The head lights shall be provided in suitable waterproof enclosures conforming to IP 65. The head light shall work in neutral section also.

4.4.15.3 Marker/ Ditch Lights

The Locomotive shall be provided with four marker/ ditch lights on each end. The marker/ditch lights shall have high reliability and long life. They shall be provided in suitable waterproof enclosures conforming to IP 65 and window toughened front glass. The visibility of these lights, in the vicinity of the Locomotive, shall be up to a distance of 60 meter. The marker/ditch light shall work in neutral section also.

4.4.15.4 Flasher Lights

Two flasher lights, one at each end of the Locomotive, shall be provided. It shall be designed to provide 40 ± 5 flashes per minute. It shall emit sufficiently bright amber-yellow light with dominant wavelength of 590-595 nanometers to be visible at a distance of 2 Kms. in clear daylight and not be affected by sunlight glare. The lux measured in axial direction shall not be less than 500 lux at 1 meter and 55 lux at 3 meters. The flasher lights shall be provided in suitable waterproof enclosures conforming to IP 65. These shall work on battery supply. The flasher light shall work in neutral section also.

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

4.4.16 Speed indicating and recording equipment

The Locomotive shall be provided with speed indicating-cum-recording equipment in each cab. The speed indicating-cum-recording equipments with electrical/electronic type of drive having scale range of 0 to 140 / 150 Kmph shall be used. The equipment shall also incorporate the feature of indicating and recording kilometers traveled by the Locomotive.

4.4.17 Driver's display

4.4.17.1 Colour graphics display units for driver shall be provided in each cab on driver's desk displaying important information relevant to the driver, including operational aspects, fault status and messages. 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.

4.4.17.2 The display shall be designed to provide full guidance and assistance to the driver about the action to be taken in case of a fault. The interface shall be user friendly and there shall not be any need for a separate trouble shooting directory for the driver's use.

4.4.17.3 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 to an IP rating of IP65.

4.4.18 Insulating materials

Materials of insulation shall be suitable for use in the climatic and environmental conditions as specified in these Specifications and Standards.

4.4.19 Safety measures

4.4.19.1 Standard protective systems, shall be provided, in accordance with the Good Industry Practice, for protection of the electrical equipments against abnormal currents, excessive voltages, etc., with indicating facilities, so as to ensure safe and correct operations. All equipments shall be adequately earthed, insulated, screened or enclosed and provided with essential interlocks and keys as may be appropriate to ensure the protection of the equipments and safety of those concerned with its operation and maintenance.

A sensitive and reliable protection arrangement against earth fault shall be provided in each circuit group.

All electrical circuits shall be fully insulated from the superstructure on both the positive and negative sides and the super-structure shall not be used as a part of any earth return circuit.

4.4.19.2 Fire prevention measure

The design of equipment shall incorporate all measures to prevent fires and shall be such that should any fire take place, the effect shall be minimized and no spread of fire shall take place. Materials, which are not fire-retardant, shall not be used.

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

All safety features in design, construction and materials used shall conform to the best safety standards and shall in particular prevent fires in Locomotives in accordance with Good Industry Practice.

The Locomotive shall be provided with one fire extinguisher of suitable capacity in each driver's cab in accordance with Good Industry Practice for protection of machine room equipments from fire. These fire extinguishers shall be manually operable by the driver.

The Locomotive shall be provided with a fire extinguisher pipe line to match the equipment layout within the machine room. This shall be connected with the fire extinguishers provided in both the driver's cab.

4.4.19.3 Fire detection and alarm system

A reliable fire detection and alarm system in accordance with Good Industry Practice shall be provided. The fire detection system shall detect fires in the machine room and shall be suitably interfaced with the vehicle control unit to notify the driver.

4.4.20 Event recorder

The event recorder shall monitor and record various events so that data is available for analysis to assist in determining the cause of accident, incident or operating irregularities. The equipment 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). Most recent data for below mentioned events for a minimum of the last 2 hours in loop form shall be recorded.

The following parameters shall be recorded:

(a) Speed in Kmph;

(b) OHE voltage;

(c) OHE current;

(d) tractive/braking effort;

(e) battery voltage;

(f) brake pipe pressure;

(g) brake cylinder pressure;

(h) cab1/cab2 activated cab;

(i) pantograph up/down position;

(j) status of main circuit breaker i.e., open/close;

(k) mode of operation i.e., traction mode/braking mode;

(l) direction of travel i.e., forward/reverse with respect to activated cab;

(m) head light status on/off;

(n) flasher light status on/off;

(o) horn status on/off;

(p) status of penalty brake application;

(q) status of emergency brake by assistant driver;

(r) wiper on/off;

(s) vigilance control;

(t) wheel slip/slide; and

(u) any other parameter 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, if capable of downloading whilst the Locomotive is moving, shall be capable of continuous recording during the 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.

4.5 General mechanical design

4.5.1 The Locomotive shall be aerodynamically designed to reduce wind resistance/drag. The overall dimensions of the cab shall take full advantage of the overall moving dimensions specified in Clause 2.5 of these Specifications and Standards. All major mechanical components shall be designed for a life of 35 years.

4.5.2 The general layout of the equipments in the Locomotive shall ensure equitable weight distribution. The tolerance in working order shall be limited to ± 2 % for axle load and ± 1 % for total Locomotive weight. Difference in weights on different wheels of the same bogie shall not exceed 4% of the axle load.

4.5.3 The general lay out of the equipments in the Locomotive shall ensure availability of walk way envelop of at least 1.83 m height and 600 mm width inside the Locomotive from one end to the other end of the Locomotive. There shall be a space envelop of 640 mm x 1500 mm x 575 mm (WxHxD) available in the machine room for the provision of a Train Protection and Warning System (TPWS) in the future by the Government.

4.5.4 The mechanical design of the Locomotive shall be suitable for axle load of 25 + 2% tonnes (Locomotive weight of 150 + 1% tonnes). Provision shall be kept in the design to enable ballasting of the Locomotive so as to increase the axle load to 25 tonnes from 22.5 tonnes. The Company shall indicate the scheme to be adopted for increasing the axle load in the Design package. The ballast weight(s) shall be able to be fitted without relocation of equipment.

4.5.5 Adequate safeguards such as anti-collision post and anti-climbing bars shall be provided to minimize damage to the Locomotive and human life during collision/derailment. The front portion shall be provided with rugged cattle guard that can withstand collisions with animals weighing up to 600 kg and shall be strong enough and profiled to prevent the entry of animals under the Locomotive after collision.

4.5.6 The Locomotive shall be designed, taking sufficient precautions to prevent water penetration inside the Locomotive, so as to allow periodic cleaning of the Locomotive in automatic washing facilities by spraying liquid detergents and water.

4.5.7 Couplers and Buffers

4.5.7.1 The Locomotive shall be equipped with high tensile automatic center buffer coupler (transition) with AAR "E" type coupler head and with AAR "F" type shank and AAR "F" type yoke and screw coupling in accordance with RDSO drawing No. SKDL 2494. It shall conform to AAR specification No. M-211 with grade E steel. The gathering range of coupler shall be sufficient for proper functioning of the coupler including locking on curves of 175 m radius and 1 in 8-½ turnouts. The coupler shall be located at the height of 1090+15/-5 mm from rail level. Vehicle draft gear capacity and performance shall be compatible with the design buff and draft forces of 400 tonnes as specified in Clause 3.1 of these Specifications and Standards.

4.5.7.2 Side buffer

Side buffers shall be provided to suite passenger train operations also in case of emergency. Side buffer shall be of 1500 kgm in capacity to drawing No. SKDL 4561. The locations of side buffers shall be as given below:

(i) Distance apart for centre of buffers 1955 mm

(ii) Maximum height above rail level for centers of buffers 1105 mm

(iii) Minimum height above rail level for centers of buffers under worst condition of lowest wheel diameter and serviceable suspension springs 1030 mm

4.5.7.3 Multiple unit coupling

The electrical coupling of the Locomotives in multiple formation shall have a UIC coupler. To provide redundancy two couplers shall be fitted.

4.5.7.4 Pneumatic coupling

The pneumatic hoses shall be compatible with that of the existing rolling stocks of IR.

4.5.8 Wheel, axle & axle journal / axle box roller bearing

4.5.8.1 Wheel

Wheel shall conform to the following:

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

(ii) the wheel shall be designed for nominal 25 + 2% tonnes axle load and dynamic augment of 100% over vertical static load;

(iii) wheel tread diameter of 1140 mm (in new condition) shall be provided while maintaining leading parameters (e.g. gauging, buffer/CBC height) of Locomotive according to Clause 2.5 and 3.1 of these Specifications and Standards;

(iv) wheel shall be able to withstand heat input of 35 kW minimum for at least 45 minutes without any detriment;

(v) the distance between the inside gauge face of the rim of the wheels on the same axle shall be 1596 ± 0.5 mm;

(vi) wear adapted profile as shown in drawing no. SK.DL-2561, Alt.8 placed as Annex 2 shall be provided on all wheels;

(vii) dynamic balancing as 75 gm-m maximum residual imbalances of wheels shall be conducted ;

(viii) all punching shall be only at the hub portion in hot condition not falling in machining area; and

(ix) the wheel shall be designed so as not to have a finite fatigue life.

4.5.8.2 Axle

Axle shall conform to the following:

(i) The axle material shall be in accordance to IRS specification no. IRS R-43;

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

(iii) Hollow axles shall not be acceptable;

(iv) axles shall be designed so as not to have a finite fatigue life;

(v) the axle shall be designed for a load of 25 tonnes + 2%. Dynamic augment of 50% of the vertical journal load shall be used in calculating the axle stresses in addition to the vertical and horizontal forces and moments;

(vi) axle shall be tested in accordance with IRS R-43; and

(vii) the design of the Locomotive shall be capable of wheel floating and the Company shall provide know how and necessary wheel floating / towing arrangement for use in case of axle box/ MSU bearing failure.

4.5.8.3 Axle journal / axle box roller bearing

Axle journal/ axle box roller bearing shall conform to the following:

(i) Roller bearing supplied by manufacturer approved by UIC/AAR to cater for the axle load prescribed under dynamic loading conditions and track geometry indicated in Clause 1.14 of these Specifications and Standards, shall be used; ;

(ii) static and dynamic load rating, safety factor and L-10 life calculation based on ISO: 281 & ISO:76 shall be given. Value of all parameters required for detailed calculation shall be provided. The life of the bearing shall be such that its replacement is not required before Periodic Overhaul Schedule;

(iii) requirements of Scheduled Maintenance, frequency of maintenance and special equipments and skills required for maintenance shall be indicated in the Maintenance Manual;

(iv) type of grease and quantity for initial filling shall be indicated in the Maintenance Manual and periodic interval for greasing shall be in synchronization with Scheduled Maintenance; and

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

4.5.8.4 Components including wheels, secured to the axle by interference fit shall be designed to remain secure over appropriate temperature ranges, in accordance with the Good Industry Practice. The design of the complete wheel set shall include suitable corrosion protection measures, and the maintenance instructions shall mandate means of preserving the protection over the service life.

4.5.8.5 The wheel set shall be designed so as to facilitate non destructive testing of the axle in Maintenance Depots.

4.5.8.6 The design of the Locomotive shall allow wheel sets to be machined on under-floor wheel lathes.

4.5.9 Underframe

4.5.9.1 Design of the under frame/body of the Locomotive shall be made to safely withstand the following loading conditions:

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

(ii) lifting of the Locomotive at one end of the headstock with the adjacent bogie suspended from the under frame and the other bogie resting on the rails/ground representing the conditions during the re-railing operations after an accident;

(iii) lifting the entire Locomotive including the bogies at the jacking pads using jacks/ overhead cranes;

(iv) lifting the entire Locomotive without the bogies at the buffer beams using jacks/ overhead cranes; and

(v) stationary Locomotive under a squeeze load of 400 tonnes applied at the center buffer coupler.

4.5.9.2 The design of the under-frame and body of the Locomotive shall be such that the stresses shall not exceed endurance limit of the material for loading conditions prescribed in Clause 4.5.9.1(i). The pivot arrangement transferring forces between body and bogies shall be designed and manufactured not only for the repeated traction and braking cycles, but also for repeated shunting shocks.

4.5.10 Bogie

4.5.10.1 Design of bogie:

(i) The bogie shall be capable of running up to a test speed of 110 Kmph. It shall also be capable of being run at a test speed of 135 Kmph. Simulation studies shall be carried out by the Company, to check stability of the locomotive, to confirm stability at 135 kmph. The bogie shall be provided with two stage suspension, suitable damping both in lateral & vertical modes and controlled guidance of the axle. The bogie design shall be suitable for the existing tracks of IR, with suitable arrangements to ensure minimum wear to wheels & track with minimum angle of attack. If bogie is provided with pedestals; the pedestal and axle box wear liners shall be of non-metallic wear resistant self-lubricating material; and

(ii) the bogie shall be so designed that in normal running condition, the stresses at critical locations are always within the endurance limit of the material employed together with appropriate safety factor. The design shall be based on 50% dynamic augment loading over the vertical static load.

4.5.10.2 The bogie frame shall be tested for static and dynamic load tests (10 million cycles) in accordance with UIC standards. The bogie frame shall not show any sign of deformation/development of cracks during the above tests. The stress values shall remain within 60% of yield stress limit except 2g (two times the static vertical load) & 3g (three times the static vertical load) cases where it shall be restricted to yield stress limit.

4.5.10.3 The springs shall be designed and manufactured for reliable service with respect to its specified characteristics for a minimum period of 18 years. Spring stresses under conditions of maximum dynamics augment shall be within endurance dynamic limits of the spring material. The springs, if metallic, shall be painted with suitable anti-corrosive paints.

4.5.11 Braking requirements and Brake equipment

4.5.11.1 The Locomotive shall be fitted with computer controlled graduated air-brake system with data logging and self diagnostic features using integrated panel, consisting of multi layers plates (not less than three), on which brake valves shall be directly mounted, with the provision of pneumatic interconnections of valves within the panel itself thereby avoiding any need of external piping. The brake system shall be compatible with trailing stock fitted with twin pipe gradual release air brake system in accordance with RDSO specification No. 02-ABR-02.

4.5.11.2 The electrical regenerative braking system shall be the primary braking system of the Locomotive. The braking system of the Locomotive shall ensure that the air brake of the Locomotive is applied only when the electric braking system is not capable of achieving the required braking force, or in case the electric brake has broken down, so as to limit the wear of mechanical parts of the air braking system by using the electric braking system to its maximum capacity and also for making optimum use of power regeneration. The braking system of the Locomotive shall also ensure that when the electric brake is

insufficient to provide the required braking effort, the necessary proportion of the air brake of the Locomotive, superimposed on the electric brake, is applied (system also known as "brake blending"). The driver shall be able to control the train with regenerative brakes and/or using the automatic train brakes.

4.5.11.3 The Locomotive shall be provided with self-lapping type independent direct acting brake valve with a simple arrangement of adjusting the maximum brake cylinder pressure. The capability of holding train loads in tonnes, in falling 1 in 80 and 1 in 100 gradients, with only application of independent direct acting brake, shall be specified by the Company.

4.5.11.4 The automatic brake valve shall be of self-lapping type and shall have 'release' and 'run' positions in accordance with the UIC code. The 'release' position shall be spring-loaded.

4.5.11.5 Provision of isolating position in the independent direct acting brake valve shall be provided.

4.5.11.6 The direction of rotation of driver's automatic and independent direct acting brake valve handles shall preferably be on the horizontal plane and in anticlockwise direction, as seen from top, for 'application' of brake.

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

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

4.5.11.9 In case of parting between the coupled Locomotives, the brakes on the Locomotives shall be applied automatically. It shall also be possible to apply independent brakes on the leading Locomotive in case of parting.

4.5.11.10 Emergency brake valve shall be provided on right hand side in cab near assistant driver for direct opening of air brake pipe during emergency by the assistant driver, in addition to independent and automatic brake valves. During emergency brake application by emergency brake valve or through driver's automatic brake valve, automatic Locomotive power cut off shall take place.

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

4.5.11.12 Twin pipe air brake system shall run from end to end of the Locomotive with two isolating cocks at either end terminating outside. There shall also be a provision of additional isolating cock on both pipes at either end, located below each buffer beam of the Locomotive.

4.5.11.13 All piping shall be of stainless steel with flare less compression fittings for tropical conditions. Copper pipes can be used, as alternative, inside machine room and drivers' cab.

4.5.11.14 Isolating valves and switches shall be provided to enable parts of the system to be isolated. All isolating valves that require operations by train crew in normal operation or in emergencies shall be easily accessible either from within the Locomotive or from track level as appropriate. Isolating cock handles shall lie parallel to the pipe in which it is installed, in the normal operational (open) position, and perpendicular to the pipe in the isolated (closed) position, and shall operate in the horizontal plane only. Cable ties shall provide a ready means of identification of a cock which has been operated.

4.5.11.15 Design of the brake system and its interconnections shall be fail-safe. In the event of failure of brake equipment and brake electronics, brakes shall be automatically applied.

4.5.11.16 Use of pipe fittings with rubber 'o' rings or similar types of seal shall not be acceptable. Suitable colour coding shall be applied to all pipe work for identification. Use of flexible hoses shall be kept to a minimum.

4.5.11.17 The pneumatic valves shall not require overhauling before six years of service including rubber kit changing.

4.5.12 Brake Rigging

4.5.12.1 All wheels of the Locomotive shall be provided with either tread or disc brakes with high composition brake blocks not containing any asbestos material. With full brake pressure, the total braking force shall be 7-9% of the maximum designed weight of the Locomotive in working order. Means shall be provided to permit variation in this brake power above or below 8%. The system shall include a suitable device for automatically taking up slacks due to wheel and brake blocks wear, etc.

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

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

It shall be possible to isolate the tread brake/disc brake system individually on each bogie. The isolation device shall be easily accessible. All devices capable of isolating a portion of the brake system shall be located and protected to avoid inadvertent or malicious operation.

4.5.13 Compressed air system

4.5.13.1 Compressor

Total derated capacity (free air delivery) of the air compressors system shall be around 4000 lpm at 10 kg/cm sq. pressure, after accounting climatic conditions as specified in Clause 2.6 of these Specifications and Standards. Two or more identical compressors shall be used. The compressor(s) shall be suitable for continuous operation at a pressure of 10 kg/cm sq. (without causing high temperature, damage and unusual wear of components) with pressure governor setting to cut out at 10 kg/cm^2 and cut in at 8 kg/cm^2 and safety valve setting of 10.5 kg/cm^2. The temperature of air at the inlet of first main reservoir shall not be more than 40 degree celsius above ambient air temperature at a pressure of 10 kg/cm sq. The compressors shall be driven by dedicated electric motors. The compressor overhauling period shall be in synchronization with the Scheduled Maintenance of the Locomotive and shall not be less than six years in any case.

The motor compressor unit shall be under slung, resiliently mounted with the under frame to minimize the levels of vibrations transmitted to the Locomotive body. The mounting arrangement shall be of proven design. The compressor shall preferably be splash lubricated to avoid the need for oil pump, filter, valve, etc. The oil sump inlet shall be so designed to avoid any over filling during service. The company may offer alternative design such as, oil free compressor. Such oil free compressors can be provided in the machine room.

The intake air shall be directed through a properly designed filter, suitable for the specified dusty atmospheric conditions. The inlet air filter shall be so mounted on compressor so that it can be easily taken out for cleaning purpose. The cleaning periodicity shall not be less than six months. Arrangement shall be made so that the compressor does not start against back pressure. A non-return valve shall be provided between the compressor and the main reservoir supply line. A safety valve shall be provided to protect the compressor against excess pressure.

4.5.13.2 Air Dryer

The air delivered to the pneumatic system shall be clean and dry free from water vapor, oil and particles. A heatless regenerative type air dryer of matched capacity shall be provided between the air compressor and the main reservoir so as to provide dry compressed air to the Locomotive brake system. The air dryer shall be preceded by automatic drain valve and oil separator, which collects and discharges bulk of the moisture and oil present in the compressed air, before it enters the air dryer. Air dryer shall be so located /protected in under frame to avoid any hitting during run. Alternatively air dryer can be provided in machine room with provision of purging outside the Locomotive. A visual indication shall be provided to indicate the saturation of water vapor filter capsule externally.

4.5.13.3 Air Reservoirs

Main reservoirs of adequate capacity, made of corrosion resistant material, shall be provided on the Locomotive with provision of suitable safety valve and automatic drain valve.

4.5.14 Sanding

4.5.14.1 Pneumatic sanding gear of adequate capacity shall be provided for the leading axles of each bogie and it shall be operative in either direction of travel. Automatic sanding arrangement during wheel slipping by means of wheel slip detection system shall be provided. The sanding shall be direction selective. The Company shall install a suitable regime for the interaction between sanding and active wheel slip adhesion control system so that wheel slip adhesion control system shall not be prohibited from working.

4.5.14.2 Four sand boxes, two at the front and two at the rear of the Locomotive shall be provided. The sand boxes shall be easily accessible for filling from outside. Each sand box shall have a capacity of not less than 35 liters.

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

4.5.14.4 The sanding gear shall be capable of functioning properly in the tropical humid climate which increases the propensity of sand remaining moist. The sand ejection mechanism shall be designed such that it does not get choked due to moist sand and the design shall also consider provision of a suitable heating arrangement inside sand box.

4.5.15 Horns

Dual tone pneumatic horns without rubber parts shall be provided facing outwards at each end of the Locomotive. The horns shall be of sufficient size and power to be distinctly audible at a distance of 1 km from the Locomotive. The two horns shall have different tones but shall be in harmony with each other when blown together. Push buttons placed next to each other shall be provided on the driver side as well as on the assistant driver side for the operation of either one or both the horns at any time by the driver or assistant driver.

4.5.16 Painting and Marking

Any paint system used, shall be durable and resistant to damage, and shall ensure that the life of the coating is at least 6 (six) years before a re-paint is necessary. During this period the coating shall remain securely attached to the substrate and through normal service in freight operations.

Subject to re-painting at 6 (six) year intervals and attention provided during maintenance to attend to any damage to the paint system caused by accidental impacts, the paint system shall protect the substrate from corrosion over the design life of the Locomotive. The paint system shall be capable of withstanding the effects of any detergents used in cleaning and the use of washing machines.

Rectification of coating damage which occurs due to impacts shall be repairable at the Maintenance Depots. The Company shall describe in the Maintenance Manual the

materials, equipment and processes required for such repairs to the paint system. The paint system and the repair process selected by the Company for use on Maintenance Depots shall not cause environmental problems or hazards to personal health.

Lettering and labeling shall be applied to the Locomotive exterior and interior to inform staff of matters such as positions of equipment, safety warnings etc. Lettering and labels shall be durable.

The design of the Locomotive shall promote preservation of asset value. The design shall protect against corrosion through the use of materials and coatings as appropriate. The design of the structure shall ensure that no water traps exist. Dissimilar metal corrosion shall be prevented and anti-corrosion paint shall also be applied.

4.5.17 Driving Cabs

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

The cab shall be ergonomically designed for convenience and to minimize fatigue of the driver. Ergonomic and human engineering aspects of the cab design shall be compatible with the range 5^{th} percentile Indian adult female to 95^{th} percentile Indian adult male. The visibility diagram shall be in accordance with UIC 651.

Air conditioning including cooling, heating and ventilation arrangement shall be provided in the cab space. There shall be sufficient space for four persons in the cab. The air conditioning and heating system shall maintain temperature as per UIC 651, during summers, by compressor cut in/ cut out and between 19-21 degree Celsius, during winters and humidity between 40% - 60%. During air conditioning and heating minimum fresh air quantities shall be 1.40 m^3 / minute. In addition, two crew fans shall also be provided one each for the driver and assistant driver. Temperature and humidity indicators shall be provided in both the cabs.

All window, rearview mirror and door glasses shall be of shatterproof type laminated glass, set in sun and heat resisting synthetic rubber sections. Electric or electro pneumatic or pneumatic windscreen wipers with washers shall be provided on the look out windows with foolproof drive arrangement and emergency manual control. Rolling blinds and sun visors shall be provided on the windscreens. The front look out glass shall be plastic laminated.

4.5.17.2 The layout of the driving cab and the driving position shall be ergonomically sound enabling the driver, in the interest of safety, to concentrate his attention outside of the cab to observe line side signals and instructions as applicable. The driver shall be able to undertake this task in both seated as well as standing position. All necessary controls and instrumentation shall be presented in a manner that shall aid the correct reflex action from

the driver in both normal and emergency situations. The driving position shall be on the left side of the driving cab and the brake handles shall be located on the left hand side of the driver in the running direction. Their relative positions shall be similar to those available on IR's present electric locomotives. A second seat shall be provided for the assistant driver. Seat positions shall be adjustable.

4.5.17.3 Access to the cab shall be from either side of the cab by means of sliding or inward opening doors having minimum height of 1675 mm and minimum width of 600 mm. The door leading to machine room from cab shall open into the machine room. The cab access doors shall be provided with lock and key. The fixed front glass panel of the cab windscreen, the glasses on the doors and side windows of the cab and the fixed glass panels of the equipment compartment shall be of shatter proof laminated duplex glass.

4.5.17.4 Hinged grill for prevention of damage to the front glass panel of the wind screen shall be provided.

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

(i) Two cabinets in the rear and locker for toolbox;

(ii) one fire extinguisher in addition to the one for the equipment compartment;

(iii) one LED based rechargeable torch with socket and charger;

(iv) VCD for monitoring alertness of the Locomotive crew through multi-resetting system which resets by specified normal operational activities of the crew, in addition to acknowledgement of the vigilance check by pressing a pedal switch provided for this purpose. Absence of the normal driving functions and acknowledgement at specified interval of one minute shall cause audiovisual warning. If audiovisual warning is not acknowledged for 16±4 seconds, it shall result into emergency brake application which shall only be resettable after 120 seconds;

(v) availability of 110 volt DC supply;.

(vi) suitable trays with clamps for working time table, caution orders, walkie-talkie etc;

(vii) suitable LED based lighting in cab. There shall also be provision that during running of the Locomotives only the drivers' desk, time table and caution order area shall be illuminated so as not to reduce the visibility of driver; and

(vii) a voice recorder with sequential cyclic erasure that under any circumstances records the last 30 minutes of operation of the Locomotive. The voice recorder shall be designed to:

(a) Permit rapid extraction and analysis of data;

(b) assist retrieval of data after an incident or accident; and

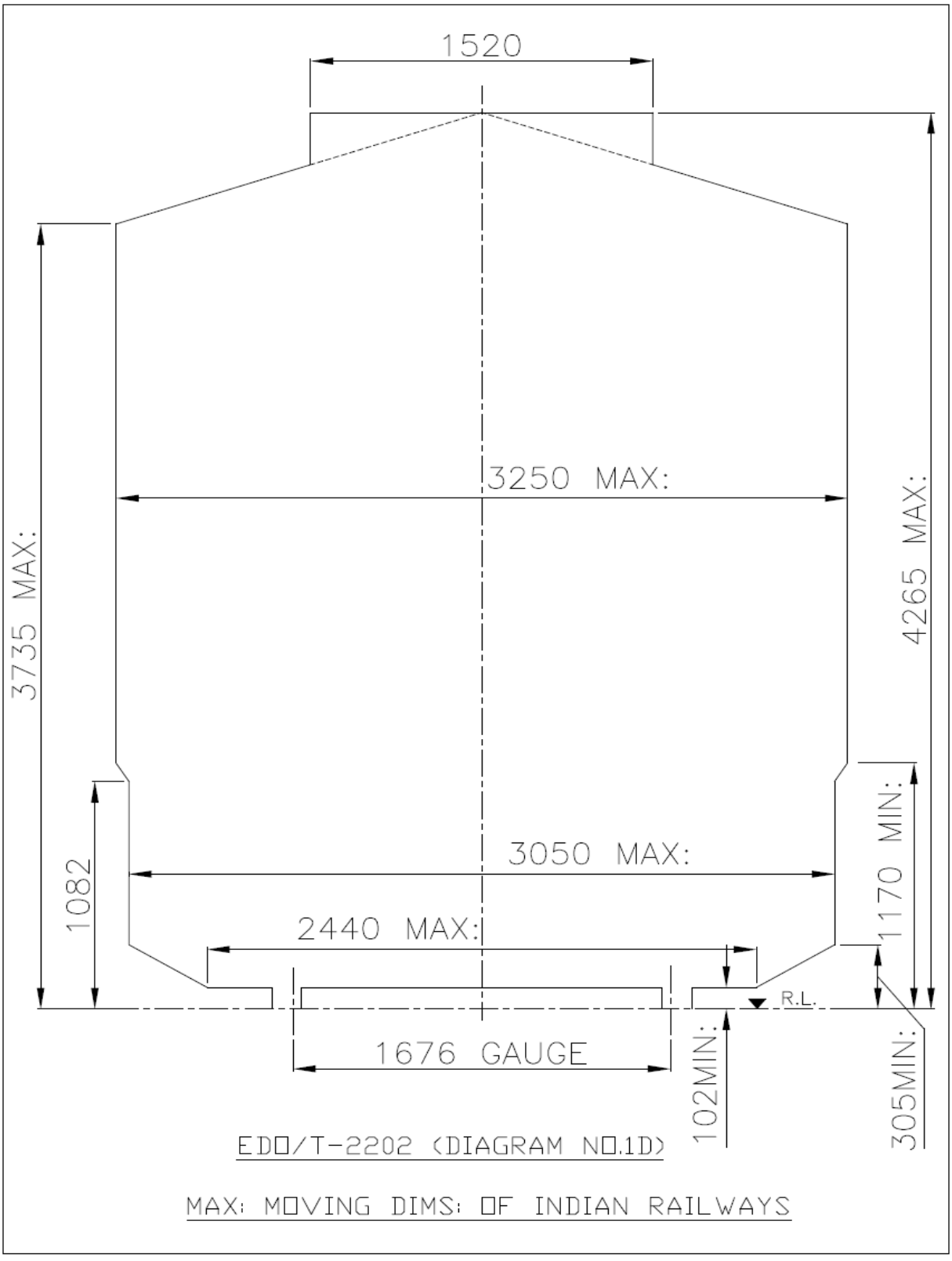
(c) mitigate the effects on recorded data of foreseeable impact or derailment.

The voice recorder shall be designed and constructed to ensure the integrity of the recorded data and the ability to extract data following an incident. The voice recorder shall be tested in accordance with a recognised international standard such as the UK Railway Group Standard GM/RT2472.

4.5.17.6 Provision shall be made to enable the Government to implement a Train Protection and Warning System (TPWS) at a future date. A space of 360 mm x 450 mm x 150 mm (HxWxL) shall be provided for the future fitment of the Driver Machine Interface (DMI).

4.5.18 The equipments in the equipment compartment shall be protected by means of expanded metal doors or panels. Glazed panels shall be provided for fittings, which require frequent visual inspection. Space provided in the corridors shall permit unrestricted movement of driving crew and maintenance staff. Detachable waterproof roof panels shall be provided in the roof for permitting removal of equipments from inside the Locomotive machine room. The joints of the roof panels shall be watertight.

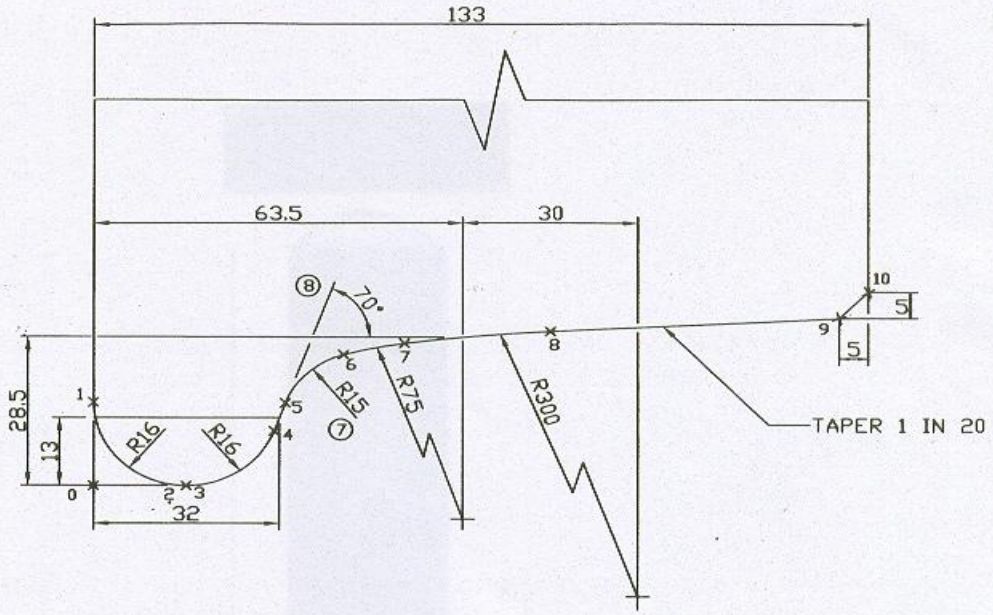
Annex 1



Prepared by	Checked by
DSE/TPL/RDSO	EDSE/RDSO

Annex 2

INDIAN RLYS. RDSO(MP) | APPLICABLE FOR B.G LOCOS. | **WEAR ADAPTED WHEEL PROFILE** FOR DIESEL & ELECTRIC LOCOMOTIVES



⑥ CO–ORDINATES ARE GIVEN BELOW:–

Pt.	X	Y
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2	16.0000	0.0000
3	16.0651	0.0000
4	31.1001	10.5277
5	33.0371	15.8495
6	43.0407	25.1503
7	53.5000	27.3251
8	78.5187	29.6295
9	128.0000	32.1035
10	133.0000	37.1035

⑦

⑥ NOTE: GIVEN POINTS CO–ORDINATES ARE ROUNDED OFF UPTO FOUR DECIMAL PLACE.

ALL DIMENSION ARE IN mm.

ALT.NO.	REF.NO.	DESCRIPTION	ALT.NOTE NO.	SIGN	DATE
⑧	–	FLANGE ANGLE 70° INDICATED.	L2–980		17.10.06
⑦	–	ROOT RADIUS CHANGED FROM R17 TO R15. CO–ORDINATES OF THE POINTS 5&6 REVISED ACCORDINGLY.	L2–977	Sd/–	07.9.06
⑥	–	DRG. REVISED & NOTE ADDED.	DV/L2/924	Sd/–	23.8.05
⑤	–	DRG. REVISED	DV/L2/XXX	Sd/–	–12.93
④	–	DRG. REDRAWN	DV/L2/452	Sd/–	5.7.89

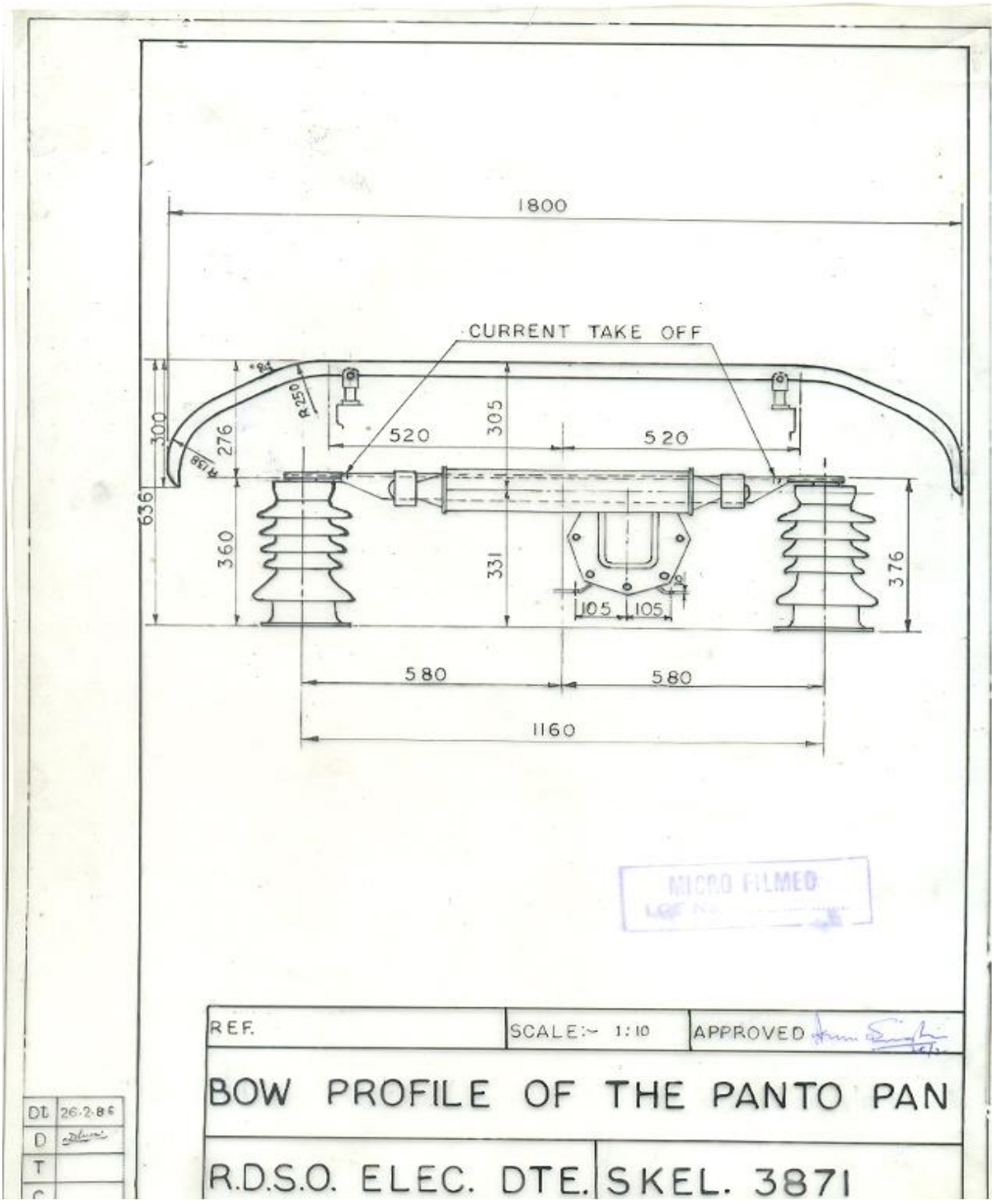
D
C
APPD.
Dt 17/10/06

SCALE 1:1 | REF: SK.DL–2561 ALT.3 | DRG NO. SK.DL–2561

FIRST ISSUED JAN,76 | SUPERSEDES ALT. 6 | SUPERSEDED BY

Prepared by	Checked by
DSE/TPL/RDSO	EDSE/RDSO

Annex 3



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