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GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS

SPECIFICATIONS AND STANDARDS

FOR

1676 mm GAUGE 9000 kW 8 AXLE

IGBT BASED 3-PHASE DRIVE

ELECTRIC FREIGHT LOCOMOTIVE

Specification No. RDSO/2006/EL/SPEC/0044, Rev'13'

Approved by	Signature
Sr. EDSE/RDSO	

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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
ASIC	Application Specific Integrated Circuit
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
FEM	Finite Element Method
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)
IC	Integrated Circuit
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
ISO	International Standards Organization
Kmph	Kilometers per hour
LED	Light Emitting Diode
MCB	Miniature Circuit Breaker
MMD	Maximum Moving Dimension
MMI	Man-Machine Interface
MMIS	Maintenance Management Information System
MSU	Motor Suspension Unit
OHE	Over Head Equipment
PCB	Printed Circuit Board
RAMS	Reliability, Availability, Maintainability and Safety
RDSO	Research Designs & Standards Organisation
SI	Systeme Internationale
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

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 Procurement cum Maintenance Agreement for Electric Locomotives;
Bo-Bo	shall mean one unit of the Locomotive consisting of two bogies, with each bogie having two wheels with two independent traction motors and the traction motor drive coupled to each wheel;
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;
Transmission and	shall mean system comprising traction gears, gear case, traction rod arrangements (if any), primary and secondary suspension springs

Suspension System	and dampers with bogie frame;
WiMax	shall mean the telecommunication technology, based on the IEEE 802.16 standard that provides wire less data, from point-to-point links to full mobile cellular type access; and
Others	any capitalized term used herein not specifically defined shall have the meaning ascribed to such term in the Agreement.

Chapter-1

General Description, Operating and Environmental Conditions

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 9000 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 twin identical Bo-Bo units, i.e., Bo-Bo+Bo-Bo, with driver's cab at each end of the Locomotive and a gangway connecting both Bo-Bo units.

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

1.1.4 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.

1.1.5 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.

1.1.6 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 1.6 in 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 sub-systems and systems shall be:

(i) IEC publications;

(ii) EN ;

(iii) UIC;

(iv) AAR

(v) IEEE;

(vi) BS;

(vii) IS; and

(viii) 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 /IEC/UIC/AAR; and

(iii) IS.

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

1.2.2 The design of the Locomotive and the sub-systems and 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 equipment used on rail vehicles	:	IEC-61287
3.	Specific rules concerning the electronic control part of converters	:	IEC-60571
4.	Electronic converter fed alternating current motors	:	IEC 60349 –2
5.	Railway application – rolling stock – Part 1: combined testing of inverter fed alternative current	:	IEC 61377-1

	motors and their control system		
6.	Guide for the evaluation and identification of insulation systems of electrical equipment	:	IEC 60505
7.	Electric railway equipment-train communication network	:	IEC 61375-1
8.	Rotating electrical machines: Functional evaluation of insulation systems	:	IEC 60034-18
9.	Railway applications – electromagnetic compatibility – Part 3-2: rolling stock – Apparatus	:	EN 50121-3-2/ IEC 62236-3-2
10.	Railway applications – electromagnetic compatibility – Part 2: emission of the whole railway system to the outside world	:	EN 50121-2/ IEC 62236-2
11.	Railway applications – compatibility between rolling stock and train detection system	:	EN 50238
12.	Transformer and chokes	:	IEC 60310
13.	Transformer oil	:	BS 149-1984
14.	High voltage AC circuit breaker	:	IEC 60056
15.	Rules for pantograph of electric rolling stock	:	IEC: 60494 Pt.I
16.	Relays, contactors and switches	:	IS 3231, IEC 60337, 60947
17.	Cables	:	IEC 60228, IS 10810
18.	Lightning arrestor	:	IEC 60099-4, IS 3070 pt III
19.	Railway applications – rolling stock equipment –	:	IEC 61373

	shock and vibration test		
20.	Programming languages for PLC	:	IEC 61131
21.	Railway applications – electric equipment for rolling stock	:	IEC 60077
22.	Electronic equipment used on rail vehicles	:	IEC 60571
23.	Power converter installed on board rolling stock – Part 1: Characteristics and test methods	:	IEC 61287-1
24.	Power converter installed on board rolling stock– Part 2: Additional technical information	:	IEC 61287-2
25.	Railway application – rolling stock protective provisions against electrical hazards	:	IEC 61991
26.	Auxiliary machines	:	IEC 60034
27.	Power factor correction	:	IEC 60871
28.	Control cubicle	:	IEC 60068
29.	Batteries	:	IEC 60623
30.	Degree of protection provided by enclosures	:	IEC 60529
31.	Rules for installation of cabling	:	EN 50343
32.	AAR approved couplers and coupler yokes	:	M-211
33.	Wheels	:	IRS R-34
34.	Axle	:	IRS R-43
35.	Railway applications, welding of railway vehicles and components. Inspection, testing and documentation (The Company shall, no later than the 5th (fifth) anniversary of the Appointed Date,		EN15085

	demonstrate compliance to the EN 15085)		
36.	Air brakes	:	RDSO's specification No. 02-ABR-02
37.	Schedule of Dimension for broad gauge	:	IR Schedule Of Dimension for Broad Gauge, revision 2004
38.	Reliability of electronic component	:	IEC 61709
39.	RAMS	:	EN 50126/ IEC 62278
40.	Metallised carbon strip for pantograph	:	RDSO's technical circular no. ELRS/TC/0071 (rev.'0')

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 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 Reliability, Availability, Maintainability and Safety (RAMS)

1.3.1 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 safetyshall form an integral element of these Specifications and Standards.

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

1.3.2 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, Transmission and Suspension System, high voltage equipments, blowers and other auxiliary machines, such that it will provide a high level of dependability.

1.3.3 There shall be an efficient means of operation of the Locomotive after all failures in accordance with Good Industry Practice.

1.3.4 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.

1.3.5 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.

1.3.6 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.

1.4 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 contact wire height in mid span	Normal OHE	High rise OHE
	5.5 m from rail level	7.42 m from rail level
Max. contact wire height	5.8 m from rail level	7.52 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	

1.5 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); 2500 m radius (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	185 mm	
Maximum cant deficiency	100 mm	
Permissible track tolerances:	**BG Main Line**	**BG High Speed Route (C&M1 volume 1)**
➢ Unevenness (3.6 m base)	< 15 mm	< 10 mm
➢ Twist (3.6 m base)	< 2.78 mm/meter	<2.08 mm/meter
➢ Gauge variation	< ± 6 mm	< ± 3 mm
➢ Alignement (versine on 7.2 m chord)	< 5 mm	< 5 mm
Gauge widening:		
➢ On curves of > 350m radius	-5mm to +3mm	
➢ On curves of < 350m radius	Up to +10mm	

1.6 Climatic and Environmental Conditions

The climatic and environmental conditions prevailing in India 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)
➢ Humidity	100% saturation during rainy season
➢ Solar radiation	1 kW/m^2
➢ 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

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	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

1.7 Signal and Telecommunication Installations

1.7.1 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.

1.7.2 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 for stages of operation of 100% down to 50 %, working in a train:

	Interference Current	**Limit**
1.0	Psophometric current	10.0 A
2.0	DC component	4.7 A
3.0	Second Harmonic component (100 Hz) and 83.33 Hz component	8.5 A
4.0	1400 Hz up to 5000 Hz	400 mA

5.1	>5000 Hz up to 32000 Hz	270 mA
5.2	39500 Hz up to 43500 Hz	270 mA

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

1.7.3 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 within Schedule H and the results shall be provided in a Type Test report.

1.7.4 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 1.7.2 of these Specifications and Standards these limits shall be applied subject to provisions made in Clause 1.2.3 of these Specifications and Standards.

1.8 Definitions and Interpretation

1.8.1 The rules of interpretation as specified in Clause 1.2, 1.3 and 1.4 of the Agreement shall apply *mutates mutandis* to these Specifications and Standards.

1.8.2 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.

1.8.3 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- 2

Performance Requirements

2.1 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	8
Weight	180 tonnes ± 1% upgradable to 200 tonnes ± 1%.
Maximum operating speed	100 Kmph (upgradable to 120 Kmph)*
Test speed	10 % more than maximum operating speed
Buffing load	The Locomotive shall be designed to withstand static buffing load of 400 tonnes at maximum speed of 110 Kmph
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 worn	102 mm

wheels	
Wheel diameter	1250 mm (in new condition)
Overall moving dimensions	The Locomotive with new wheel shall have overall moving dimensions within MMD according to RDSO drawing number EDO/T-2202 (Diagram No. 1D) (Annex – A1)
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

(* 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.)

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

(i)	Starting tractive effort under dry rail condition (up to speed not less than 10 Kmph.)	Not less than 706 kN with 22.5 tonnes axle load Not less than 785 kN with 25 tonnes axle load
(ii)	Continuous rated speed	60 Kmph
(iii)	Maximum operational speed	100 Kmph (upgradable to 120 Kmph)
(iv)	Continuous rated power at rail	Not less than 9000 kW at all speeds from continuous speed to maximum operating speed
(v)	Regenerative brake effort	25 % of gross weight over the speed range of 10 Kmph to 65 Kmph without slipping, and as limited by adhesion for higher speeds

(vi)	Pneumatic brake effort	7% - 9 % of gross weight
(vii)	Emergency braking distance (with pneumatic brake only)	900 m maximum for light engine from 100 Kmph to standstill on level tangent dry track
(viii)	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
(ix)	Independent Brake holding capability	Capability of holding a 300 tonnes train on 1 in 37 gradient
(x)	Capability to work in flood water	The Locomotive shall be designed to permit its running at 10 Kmph in flood water level of 102 mm above rail level

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 1.4 of these Specifications and Standards. Variation of power, if any, in the specified occasional maximum to minimum voltage range shall be specified. There shall be no reduction in the maximum tractive effort in the maximum to minimum voltage and frequency range.

2.3 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 87 % 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 shall not be less than 96% 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.

2.4 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 indicated.

2.5 During normal operation, the Locomotive shall be able to start and haul freight trains, in a compensated up gradient of 1:150 at a speed of at least 60 Kmph, weighing 6000 tonnes with 22.5 tonnes and weighing 6300 tonnes with 25 tonnes axle load.

2.6 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. 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.

2.7 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

2.8 Duty Cycle

2.8.1 The Locomotive shall be available for operational service in accordance with Availability requirements of Clause 21.2.

2.8.2 Each Locomotive shall be capable of travelling 200,000 km in service annually without any detrimental effect on the performance of the Locomotive.

2.8.3 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.

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 %

Chapter - 3

Technical requirements of system/sub-systems

3.1 General

3.1.1 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.

3.1.2 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 1.6 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.

3.1.3 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 1.6 of these Specifications and Standards and with half worn wheels.

3.1.4 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.

3.1.5 The maximum starting tractive effort shall be achieved gradually, without producing jerks in the train being hauled 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.

3.1.6 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.

3.1.7 It shall be possible to use the Locomotive in multiple unit operations of up to two Locomotives in one group. The control of both the Locomotives shall be achieved from either of the Locomotives being used under the multiple unit operations. Provision shall be made to enable the driver in the driving cab to monitor the parameters of the other Locomotive as well as to identify the fault in both the Locomotives.

3.1.8 Provision shall be made in the control circuitry of the Locomotive, to limit the starting tractive effort to predefined values when required during operation. The two predefined values shall be 300 kN and 529 kN per Locomotive.

3.1.9 Provision shall be made to enable the operation of the Locomotive under inching control mode at a constant speed settable by the driver in steps of 0.1 Kmph, in the range from 0.5 to 1.5 Kmph in yards for a load not greater than 7600 tonnes and on a gradient of 1 in 1000 or flatter . It shall be possible to change from inching control mode to normal mode and vice versa by the driver depending upon his requirement. Provision shall also be made to enable operation of the Locomotive in shunting mode up to 15 Kmph in yards for a load not greater than 7600 tonnes and on a gradient of 1 in 1000 or flatter.

3.1.10 The Locomotive shall be provided with a speed control system, which shall enable the driver to pre-set the speed at which the Locomotive is desired to run the train irrespective of the track profile. The speed control shall work within the limits of maximum electrical performance as specified in clause 2.2 of these Specifications and Standards. The selection of speed shall be possible by press of 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 master/ brake controller or as required from safety considerations.

3.1.11 Wireless remote control

The Locomotive shall be suitable for synchronous control system through wireless signals between Locomotives which may consist of up to two Locomotives, distributed in the train formation at the head of the train, in the middle or at the rear end of train for operation of heavier and longer trains. The control and operating signals from the lead Locomotive shall be transmitted to the trailing Locomotives through radio transceiver to allow all the trailing Locomotives to be operated in synchronization with a single driver control from the lead Locomotive. Encryption shall be provided for commands sent from the lead Locomotive and feedback messages from the trail Locomotives for security purposes. The display in the driver's cab shall indicate the status of feedbacks received from the trailing Locomotives. It shall be possible to view the status of important and vital parameters of all the trailing Locomotives from the leading Locomotive, which are considered necessary for safe and trouble free operation, by the driver. In the trailing Locomotives, train lines shall be driven

based on the commands received from the leading Locomotive. Interface shall be provided for air brake control in the trailing Locomotives, from the commands from leading Locomotive. It shall be possible to use any Locomotive in leading or trailing position.

3.1.12 Redundancy shall be built in with the design of the sub-systems and systems in order to ensure reliability and availability. In the vital units of the power control circuit, where any defect/failure of a component would cause complete failure of Locomotive's electrical system, suitable redundancy shall be provided preferably with automatic substitution features to avoid Locomotive failure due to such defects. The power supplies to the control circuit shall be hot redundant.

3.1.13 The power drawn by the pantograph of the Locomotive from OHE shall be at unity power factor subject to the interference levels as specified in clause 1.7 of these Specifications and Standards.

3.1.14 Pantograph bouncing shall not adversely affect the propulsion equipment.

3.1.15 There shall be provision of energy metering of the Locomotive for the monitoring and recording of energy consumption and regeneration.

3.1.16 There shall be provision of receiving shore supply of 415 volts, 50 Hz, 3 phase supply, on both ends of the Locomotive, for testing, movement of the Locomotive up to maximum speed of 2 Kmph in a locomotive shed/ workshop under no OHE area and for battery charging.

3.1.17 The cooling air for traction motors shall be drawn from outside the Locomotive through filters located in the sidewall or in the roof of the Locomotive. The cooling air for the other equipments, if taken from outside the Locomotive, shall also be drawn through filters located in the sidewall or in the roof of the Locomotive. Air duct design and filter arrangement on side walls and roof shall be such so as to prevent ingress of water from these locations. 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.

3.1.18 The machine room shall be adequately pressurized and the filters shall be designed to prevent dust ingress in the machine room. If the machine room air is drawn from outside of the Locomotive, 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. When air is recirculated inside the machine room for ventilation of sub-systems suitable filters, as may be required, shall be provided in order to satisfy the requirements of Clause 3.1.1 of this Specifications and Standards.

3.1.19 Equipment compartments housing relays, contactors, electronic control panels, etc., shall be suitably designed to prevent the ingress of dust and water.

3.2 Electrical

3.2.1 The two Bo-Bo units of the Locomotive shall be connected at 25 kV level, through a 25 kV HT coupler so that in the event of failure of one HT equipment including pantograph, main circuit breaker and HT coupler, the whole Locomotive can still be powered.

3.2.2 Pantographs

3.2.2.1 The Locomotive shall be equipped with two pantographs. The pantograph selector switch shall be provided in the driver's cab for raising either or both of the pantographs. The raising or lowering of the pantograph, with the Locomotive in motion, shall not cause any undue disturbance to OHE.

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

3.2.2.3 The profile of the pantograph shall be in accordance with the drawing no. SKEL-3871 enclosed as Annex-A3. Metalised carbon strip complying with RDSO's technical circular no. ELRS/TC/0071 shall be used on the pantograph.

3.2.2.4 The pantograph shall be air operated type and suitable to work in areas having high wind pressure as specified in Clause 1.6 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 1.4 of these Specifications and Standards.

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

3.2.3 Main circuit breakers

At least two main circuit breakers, one on each Bo-Bo unit, shall be provided.

3.2.4 Lightning arrestor

Two metal oxide gapless lightning arrestor, on each Bo-Bo unit shall be provided on the roof of the Locomotive for protection against the line voltage transients caused by lightning and system switching.

3.2.5 Main transformer

3.2.5.1 Fixed ratio main transformer shall be provided with multi-traction windings suiting the requirements of power converter and with or without auxiliary winding(s) for the auxiliary system.

3.2.5.2 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.

3.2.5.3 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.

3.2.5.4 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.

3.2.5.5 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.

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

3.2.5.7 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

3.2.6 Power converter

3.2.6.1 The voltage rating of IGBT 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.

3.2.6.2 The wheel slip detection and correction system shall be an integral part of the control system of the power converters/inverter 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 / skidding.

3.2.6.3 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.

3.2.6.4 In the event of any earth fault or phase to phase fault in the traction motor(s), the protection scheme of the converter shall prevent any damage to the converter.

3.2.6.5 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 or combined line converter per bogie and independent drive inverter per axle; and

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

3.2.6.6 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.

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

3.2.7 Traction motor and drive

3.2.7.1 The traction motor shall be designed for climatic and environmental conditions as specified in clause 1.6 of these Specifications and Standards

3.2.7.2 The traction motor shall be suitably rated according to the Locomotive performance requirements for the 'most severe normal service' as defined in clause 2.2(a) of IEC 60077-1.

3.2.7.3 The traction motor shall be axle hung nose suspended.

3.2.7.4 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.

3.2.7.5 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.

3.2.7.6 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.

3.2.7.7 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.

3.2.7.8 The tractive effort shall be directly transferred from the traction motor pinion to the wheel gear. Lubrication system for gear/pinion shall be kept physically segregated from the traction motor bearings and suspension tube bearings. Traction motor and suspension tube bearings of both ends (i.e. driving and non driving end) shall be grease lubricated.

3.2.7.9 Maximum temperature rise of traction motor winding shall be limited to Ti – 70 degree celsius, considering 25% choking of filters.

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

3.2.7.11 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.

3.2.7.12 Harmonic/Ripple factor:

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

3.2.7.13 The L-10 life of traction motor bearings shall be 1.2 million Kms and of suspension tube bearings shall be 2.4 million Kms.

3.2.7.14 Various components of traction motor shall be manufactured with such tolerances so as to enable complete interchangeability of components from one motor to another of same design.

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

3.2.7.16 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 gears shall be in the range of 30 degree celsius above the ambient temperature.

3.2.8 Auxiliary system

3.2.8.1 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. 3.2.8.2 The auxiliary converters shall be IGBT based and forced water cooled or air cooled. 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.

3.2.8.2 Auxiliary converters of adequate capacity identical in all respects and a battery-charging unit shall be provided in each Bo-Bo unit of 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.

3.2.8.3 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.

3.2.8.4 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.

3.2.8.5 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.

3.2.8.6 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.

3.2.8.7 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.

3.2.8.8 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.

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

3.2.8.10 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.

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

3.2.8.12 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.

3.2.8.13 Battery and battery charger

(i) An automatic static battery charger fed from three phase auxiliary supply shall be provided. Its rating and charging characteristics shall be matched to the battery, by

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 battery 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.

3.2.9 Electronics, control and communication

3.2.9.1 The general provisions of this paragraph shall be applicable to all electronics used, including for power and auxiliary converters. 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 1.6 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.

3.2.9.2 Control and communication shall be as per IEC 61375. The programmable devices shall be programmed using language compliant to IEC-61131.

3.2.9.3 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.

3.2.9.4 Features of self-check and calibration shall be incorporated in the design.

3.2.9.5 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 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 fault display to driver shall also accompany the standard trouble shooting instructions in simple language. 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.

3.2.9.6 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.

3.2.9.7 It shall be possible to access all the processors of propulsion equipments within a Locomotive using a standard laptop connected to one of the ports provided on the VCU rack. Such access is needed for uploading of firmware/application program, visualization of process parameters and also force or record the same and downloading the diagnostic data. Required interfaces shall be built in the VCU so that standard laptops, with commercially available operating systems can be directly plugged to the VCU 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. This tool shall also provide detailed off line analysis facility.

3.2.9.8 The Locomotive shall be provided with remote diagnostic and tracking equipment. The equipment shall be based on GPS and GSM/GSM-R technologies and up gradable to WiMAX. This equipment shall perform the function of tracking of the Locomotive and also communicate with the Locomotive diagnostic system, and pass on this information to the central server. The central server shall be provided by the Company at any of the Company Depot(s). It shall be possible to remotely send and obtain the information stored in the diagnostic memory of the computer system, depending on availability of communication channel, for control and diagnosis, with the aim of facilitating and speeding up the maintenance process of the Locomotives. VCU shall provide for seamless integration with Maintenance Management Information System (MMIS).

3.2.9.9 The electronics shall be designed to be sealed from the remaining part of the machine room so as to ensure that there is no dust ingress whatsoever in to the electronics. For its cooling, internal ventilation arrangement along with efficient heat exchanger for removal of heat shall be provided. The electronics shall be designed with adequate margin so that there are no failures on thermal account.

3.2.9.10 The majority of control and monitoring function shall be implemented by the software so as to reduce hardware and cables.

3.2.9.11 It shall be possible to execute parametric changes in the software in respect of user's interface viz. modifying some of the permissible parameters for adjusting the characteristic within permissible range, adding/altering the protection features, if so required in future in order to improve the operation of the Locomotive. Company shall provide all necessary equipment and accessories required for the purpose. Such changes shall be conducted by the Company in consultation with the Government to meet future operational needs of IR.

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

3.2.9.13 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. Expected life of the cards, and electronics in general shall be at least 18 years under actual working conditions.

3.2.9.14 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.

3.2.9.15 The cooling arrangement of the electronics 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.

3.2.10 Control equipment

3.2.10.1 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.

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

3.2.10.3 All vital contacts for operation of the Locomotive shall be duplicated to provide redundancy.

3.2.10.4 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 pressuring the cabinets or by covering the contacts only by dust-proof covers.

3.2.10.5 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.

3.2.10.6 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.

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

3.2.10.8 Endurance tests, both mechanical and electrical, shall be in accordance with IEC 60337.

3.2.11 Master controller

3.2.11.1 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.

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

3.2.12 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.

3.2.13 Wiring and cabling

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

3.2.13.2 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.

3.2.13.3 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.

3.2.13.4 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

3.2.13.5 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.

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

3.2.13.7 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.

3.2.14 Lighting

3.2.14.1 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.

3.2.14.2 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 3.2 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.

3.2.14.3 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.

3.2.14.4 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.

The working of the flasher lights shall be so integrated with the train brake system that in the event of train parting, flasher light shall get automatically turned on and any tractive effort on the Locomotive shall be disabled until acknowledged by the driver.

3.2.15 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.

3.2.16 Driver's display

3.2.16.1 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.

3.2.16.2 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.

3.2.16.3 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 IP 65.

3.2.17 Insulating materials

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

3.2.18 Safety measures

3.2.18.1 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.

3.2.18.2 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.

3.2.19 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 30 minutes 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; and

(s) 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.

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.

3.3 General mechanical design

3.3.1 The Locomotive shall be of a 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 2.1 of these Specifications and Standards. All major mechanical components shall be designed for a life of 36 years.

3.3.2 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.

3.3.3 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.

3.3.4 The mechanical design of the Locomotive shall be suitable for axle load of 25 + 2% tonnes (Locomotive weight of 200 + 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, if so desired by IR. The Company shall indicate the scheme to be adopted for increasing the axle load. The ballast weight(s) shall be able to be fitted without relocation of equipment. It shall not be necessary to carry out any major mechanical modifications such as attention to the bogie at the time of upgrading the axle load and only attention to springs and coupler height is permitted without any extra cost. The necessary ballast, to be fitted in the Locomotive in the future shall be supplied along with the Locomotive.

3.3.5 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.

3.3.6 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.

3.3.7 Draw and buffing gear

3.3.7.1 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 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 2.1 of these Specifications and Standards.

3.3.7.2 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. SK.DL4561. 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

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

3.3.8.1 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 1250 mm (in new condition) shall be provided while maintaining leading parameters (e.g. maximum moving dimensions, buffer/CBC height) of Locomotive according to clause 2.1 of these Specifications and Standards;

(iv) heat capacity of the wheel shall be 35 kW minimum for 45 minutes;

(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 - A2 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.

3.3.8.2 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.

3.3.8.3 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 1.5 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.

3.3.8.4 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.

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

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

3.3.9 Underframe

3.3.9.1 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.

3.3.9.2 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 3.3.9.1(i) and 90% of the yield point stress of the material under those conditions.

3.3.9.3 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.

3.3.10 Bogie

3.3.10.1 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 with a change in gear ratio. 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.

3.3.10.2 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.

3.3.10.3 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.

3.3.11 Braking requirements and Brake equipment

3.3.11.1 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.

3.3.11.2 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.

3.3.11.3 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.

3.3.11.4 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.

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

3.3.11.6 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.

3.3.11.7 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.

3.3.11.8 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'.

3.3.11.9 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.

3.3.11.10 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.

3.3.11.11 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.

3.3.11.12 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.

3.3.11.13 All piping shall be of stainless steel with flare less compression fittings for tropical conditions.

3.3.11.14 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.

3.3.11.15 Emergency stop push-buttons shall be installed in each cab. Activation of the buttons shall apply the emergency brakes under all conditions, including from the inactive cabs. Activation of the emergency brake by any means shall result in the propulsion system being disabled in a safe critical manner by opening main circuit breaker and lowering pantograph. The propulsion system shall not be re-enabled until the train is at zero speed and the emergency condition has been reset.

3.3.11.16 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.

3.3.11.17 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.

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

3.3.12 Brake Rigging

3.3.12.1 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.

3.3.12.2 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.

3.3.12.3 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.

3.3.13 Compressed air system

3.3.13.1 Compressor

Total derated capacity (free air delivery) of the air compressors system shall be around 5000 lpm at 10 kg/cm sq. pressure, after accounting climatic conditions as specified in clause 1.6 of these Specifications and Standards. Two or more identical compressors, equally distributed on both Bo-Bo units of the Locomotive, 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.

3.3.13.2 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 drier shall be so located /protected in under frame to avoid any hitting during run. Alternatively air drier can be provided in machine room with provision of purging outside the Locomotive.

3.3.13.3 Air Reservoirs

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

3.3.14 Sanding

3.3.14.1 Pneumatic sanding gear of adequate capacity shall be provided for all the wheels 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.

3.3.14.2 The sand boxes shall be easily accessible for filling from outside. Each sand box shall have a capacity of 45 kgs (+/- 10%) capacity.

3.3.14.3 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.

3.3.14.4 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.

3.3.15 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.

3.3.16 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 4 (four) 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 4 (four) 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.

3.3.17 Driving Cabs

3.3.17.1 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.

3.3.17.2 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.

3.3.17.3 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.

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

3.3.17.5 Environmental noise standards

The following noise standards shall be followed.

(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 out put. 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.

(iii) 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.

3.3.17.6 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 in 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;

(v) space / room for installation of wireless set and ATP equipments;.

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

3.3.18 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.

3.3.19 Gangway

The gangway fitted between Bo-Bo units shall allow the safe movement of staff between the Bo-Bo units at any speed and over specified track configuration. The gangway shall be stable under all dynamic and aerodynamic forces including through tunnels.

A door shall be fitted at the body end. The door arrangement shall be weatherproof and capable of being locked for security if the Bo-Bo unit is parted. The door shall be capable of being clipped in the open position during running.

The design of the gangway shall not allow the ingress of water into the gangway. No water shall enter the body or structure. No significant amounts of dust or solid particles shall enter into the gangway or into the body or structure.

Lighting shall be provided to illuminate the interior area of the gangway. The gangway floor shall be non-slip and the arrangement shall not create any hazard to personnel through tripping, trapping of hand, or otherwise.

3.4 Redundancy requirements

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

(i) Breakdown of drive side converter / traction motor:

The power of the Locomotive shall be reduced only by $1/8^{th}$, only isolating the broken down equipment;

(ii) Breakdown of power unit during traction or electrical braking:

The faulty power unit may be isolated;

(iii) Breakdown of an auxiliary converter:

Redundancy in auxiliary converter shall be provided so that in the event of its failure, the traction capacity of the Locomotive does not get affected;

(iv) Breakdown in the air braking system of a bogie:

It shall be possible to isolate the air brake in the bogie;

(v) Breakdown in the electric control of the automatic air brake:

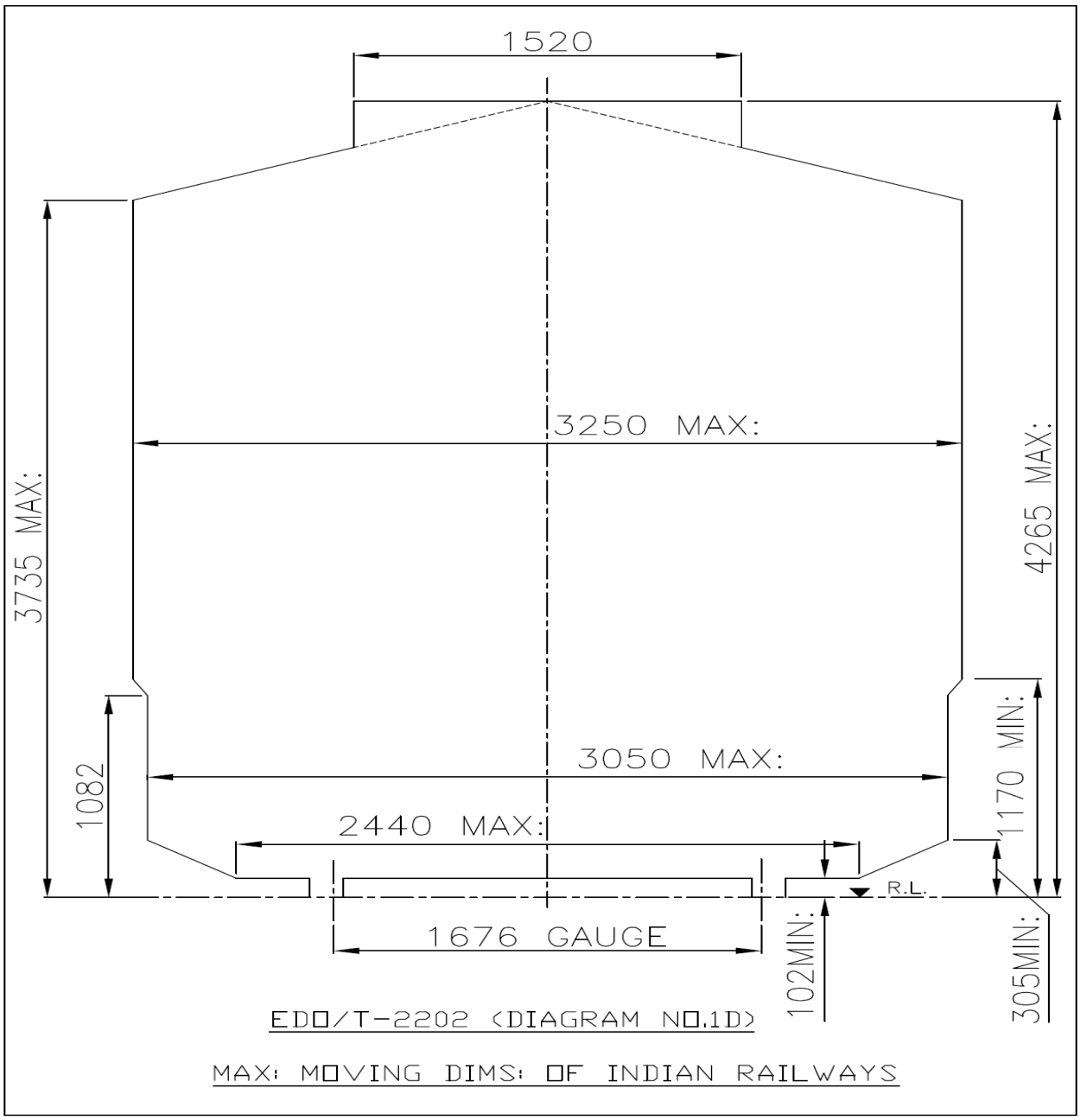
It shall be substituted by the emergency brake;

(vi) Battery charger:

The battery charger of each Bo-Bo unit shall be able to take care of battery charging needs of other Bo-Bo unit in case of failure of the battery charger; and

(vii) Control electronics (VCU) shall have adequate redundancy so that a breakdown shall not affect the traction, braking and safety related control operations.

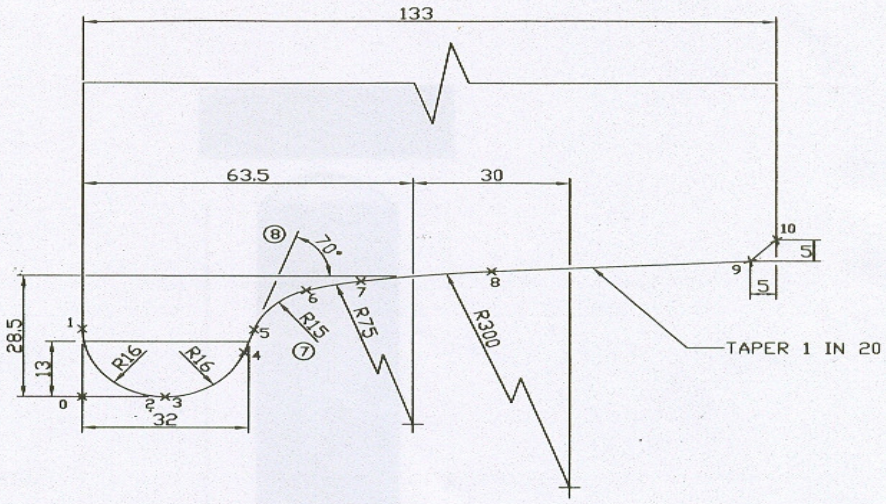
Annex - A1



Prepared by	Checked by
SSE/INSP/RDSO	DSE/TPL/RDSO

Annex - A2

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
0	0.0000	0.0000
1	0.0000	16.0000
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

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

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

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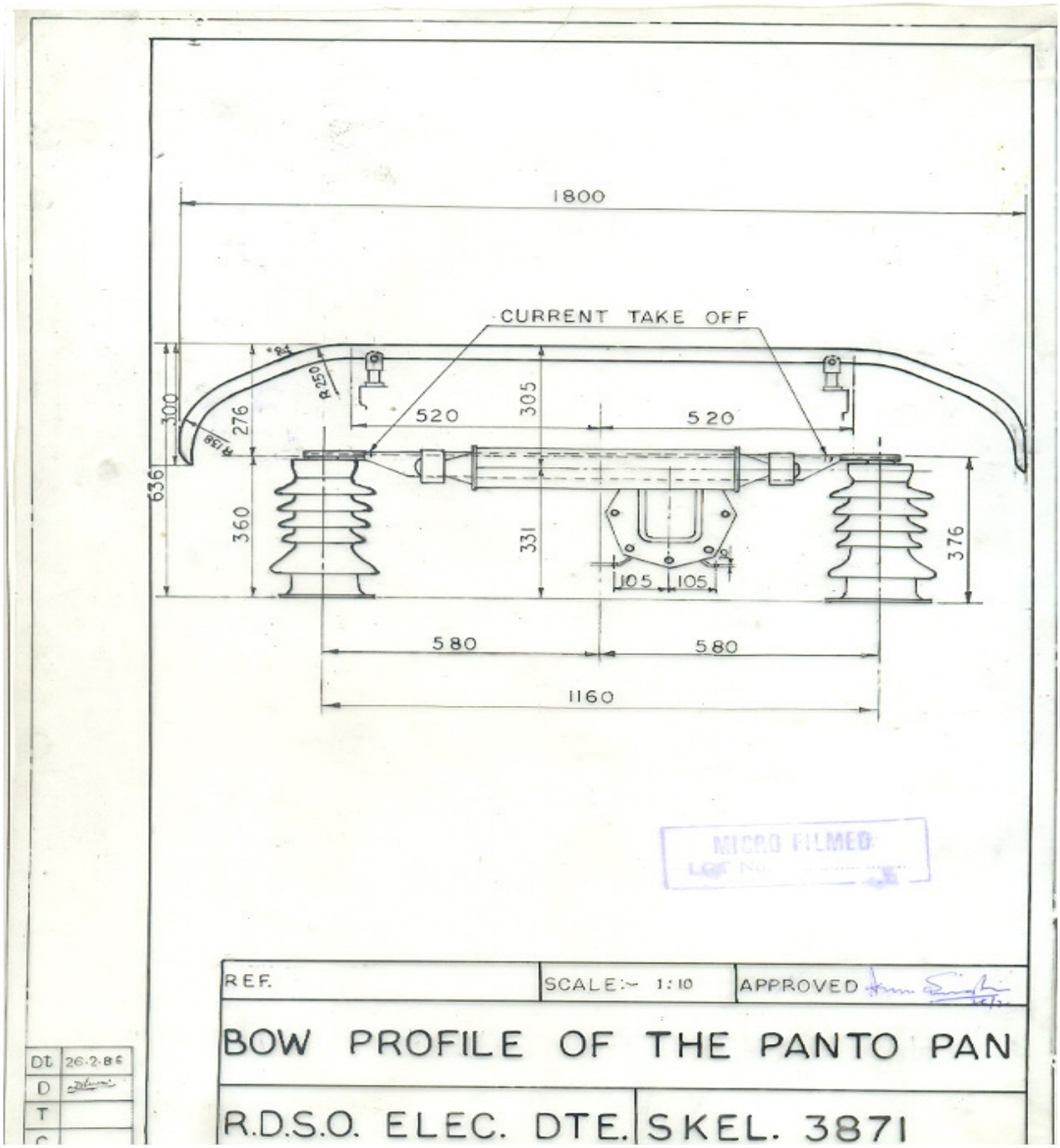
APPD.
Dt 17.10.06

Prepared by	Checked by
SSE/INSP/RDSO	DSE/TPL/RDSO

Annex - A3



Prepared by	Checked by
SSE/INSP/RDSO	DSE/TPL/RDSO

Fax: (0522)-2452581
Telephone: (0522)-2465715
Telegram : 'RAILMANAK', LKO

सत्यमेव जयते

भारत सरकार – रेल मंत्रालय
अनुसंधान अभिकल्प और मानक संगठन
लखनऊ – 226011
Government of India - Ministry of Railways
Research, Designs & Standards Organization, LUCKNOW - 226011

No. EL/3.1.35/24 Dated: 27-08-2014

Group General Manager (Elect/PS)
5th Floor,
Pragati Maidan,
Metro Station Building Complex,
New Delhi-110001

Sub: Tractive Effort Vs Speed Characteristic.
Ref: (i) DFCCIL letter No. HQ/EL/RDSO/2 dated 22-7-14.
(ii)This office letter even no. EL/3.1.35/32 dated 10-12-12 to Railway Board.

DFCCIL vide their letter under reference (i) has requested to furnish Tractive Effort Vs Speed characteristic of locomotive to be utilized on Eastern DFC as per RDSO specification No. RDSO/2006/EL/SPEC/0044 Rev.12. In this connection, the Tractive Effort Vs Speed characteristic of proposed locomotive considering 40% adhesion with 25 ton axle load forwarded to Railway Board vide this office letter under reference at (ii) are enclosed at Annexure-I.

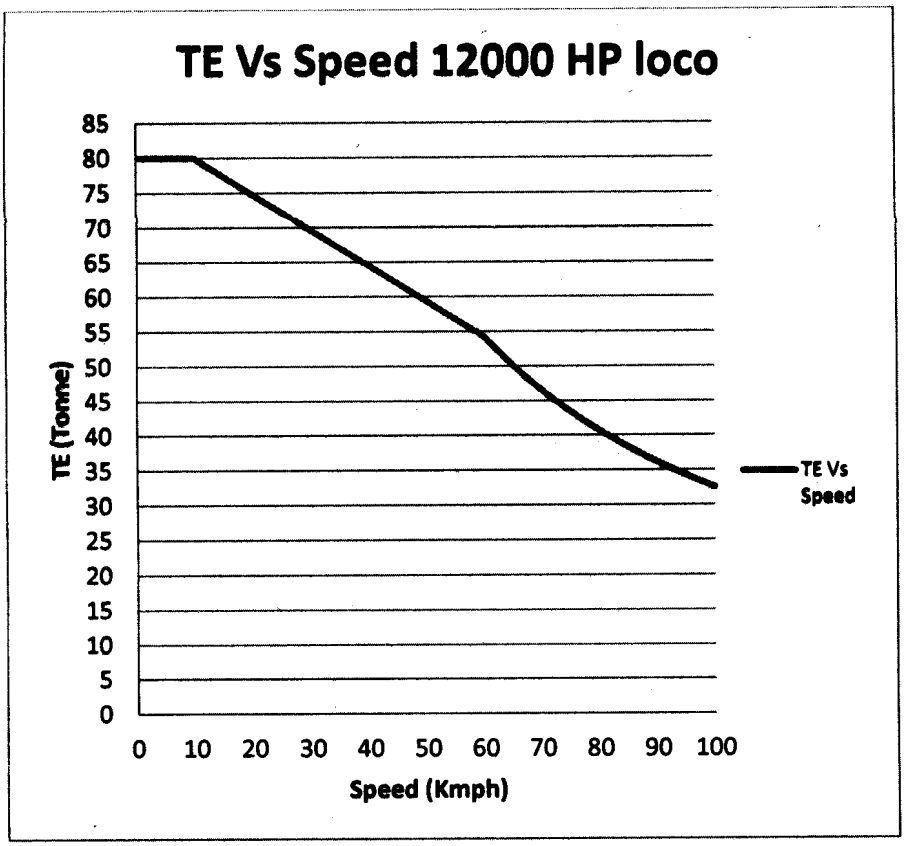
It may please be noted that enclosed Tractive Effort Vs Speed characteristic of locomotive are based on the theoretical values specified for the locomotive and actual values may be slightly different from these values.

This is for your information please

(A. K. Goswami)
For Director General (Elect.)

Encl.: As above,

Annexure-I


TE Vs Speed 12000 HP loco
TE (Tonne)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
0 10 20 30 40 50 60 70 80 90 100
Speed (Kmph)
TE Vs Speed