




सत्यमेव जयते

भारत सरकार
रेल मंत्रालय

Government of India
Ministry of Railways

**Technical Specification
For Electric Hybrid (Electric + Battery)
Locomotive**

Specification No. RDSO/2021/EL/SPEC/0143 (Rev.1)
Issued on 06.07.2022

Approved by	Signature
PED/Traction	 617122

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CONTENTS

SN	DESCRIPTION	PAGE NO.
1.	Hybrid Electric Loco Concept & Scope	4
2.	Advantages of Hybrid Electric Locomotive	4
3.	Design of a Hybrid Electric Locomotive	4 – 8
4.	Design Parameters	8 - 9
5.	Extent of modification	9 - 10
6.	Mechanical Designs	10
7.	Description of additional equipments to be installed & interfaced	10 - 11
8.	Dimensions & environmental conditions	11 - 12
9.	Weight Calculation for Proposed Hybrid Electric Locomotive (HEL)	12
10.	Simulated Performance Curve of Hybrid Electric Locomotive (HEL)	12
11.	Development and Design clearance of Hybrid Electric Locomotive(HEL)	13
12.	Inspection	13
13.	Service Trial	13
14.	Tentative General Arrangement of Proposed Hybrid Electric Locomotive(HEL) on WAG9H platform with existing Traction converter / Auxiliary converter - Annexure - I	14
15.	Tentative Weight calculation of proposed Hybrid Electric Locomotive(HEL) - Annexure - II	15
16.	Tractive effort Vs Speed characteristics of Hybrid Electric Locomotive (HEL) - Annexure - III	16

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1. Hybrid Electric Loco Concept & Scope

The Hybrid Electric Locomotive (HEL) is basically an electric locomotive with the ability to operate from Battery. Since the advent of electrified rail road, the concept of a vehicle which could be self or electrically propelled has been pursued to meet particular operating needs. End of an electrified section is always a bottleneck to the customer. Therefore, HEL can bridge this gap between electrified & non-electrified routes. Development of battery operated locomotive is an effort to reduce emission of Green House Gases (GHG) under Clean Development Mechanism (CDM) of Kyoto protocol.

This Specification defines the system and performance requirements for the design, development, construction and testing of a Hybrid Electric Locomotive. HEL can work under 25kV Over Head Equipments (OHE) as the primary power source in electrified routes and work with battery power in non-electrified sections.

2. Advantages of Hybrid Electric Locomotives

The advantages of the HEL may be summarized as follows:

- Improved operational flexibility in last mile operation on main line as well as in goods yards, sidings and in shunting operation which are non-electrified.
- In the event of major accident and natural calamities where OHE gets affected, HEL provides excellent operational flexibility to work on battery mode until normalcy is established.
- Emission free operation of HEL & dependency on diesel locos will not be there.

3. Design of a Hybrid Electric Locomotive

- Housing the on-board equipments of both electric and battery loco with a common Traction & Auxiliary control system.
- Keeping the Axle load within permissible limits of Indian Railways.
- Weight balancing of locomotives with addition of battery & its control panel.

3.1 This proposed specification is for converting the existing / being manufactured electric locomotive (WAG9H) in HEL instead of evolving a new design of a hybrid electric locomotive with transfer of technology which will be a time consuming process & may not be cost effective. The purpose of the specification is to provide the technical specification for integration of Traction battery with the

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propulsion equipment.

3.2 In general the operating characteristics of the HEL shall be similar to the base locomotive to which the retrofit has been applied. However, significant areas of improvements as the results of the retrofit is likely to be achieved in proposed design.

3.3 WAG9H is being manufactured at CLW/BLW/PLW with indigenized control software.

(i) To expedite the development of HEL, integration kit shall be made integral part of propulsion system and tender for propulsion system shall be done accordingly. This will facilitate the OEMs of propulsion system in doing the software & hardware modification thereof.

In order to interface the battery system to the WAG9H traction converter/Auxiliary converter, traction converter / auxiliary converter OEM will be responsible for design of electrical and mechanical scheme inside and outside to the traction converter.

For integration of the battery system, traction converter / auxiliary converter OEMs will have to evaluate and modify the existing design of the traction converter / auxiliary converter, any modification in hardware and software of existing traction converter / auxiliary converter will be in scope of OEM of traction converter / auxiliary converter. This adaptation design shall not be cause of any degradation in locomotive performance (for electric mode) and redundancy of the system shall not be affected.

(ii) For converting existing WAG9H locomotive into HEL, efforts shall be made by CLW/RDSO to standardize the software & hardware requirements to facilitate interfacing of any make of integration kit with any make of propulsion system. In direction to standardize the interfacing requirement, traction converter / auxiliary converter OEMs can submit the proposal for traction converter / auxiliary converter and battery system integration.

3.4 The power rating of the Battery Set will be approximately 857 kWh to keep the size of on board Battery set & accessories minimum to be accommodated in the space available & the fact that switching over to Battery mode will be required during last mile connectivity or in case of exigencies. The existing Traction Motors (TMs) will be utilized.

3.5 A design objective during the development of the HEL will be to keep the interface identical in both

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Electric & Battery Mode for crew.

- 3.6 Changeover from electric mode to Battery mode & vice-versa may be accomplished following due safety precautions. Provision of only manual change over switch from OHE to Battery & vice versa should be there during prototype development. Automatic change over switch for the purpose may be decided during regular cut in as per outcome & experience gained during prototype testing.
- 3.7 A annunciation panel shall be provided in the cab to inform crew the status of Battery mode equipment on the locomotive.
- 3.8 HEL shall be equipped with regenerative braking in both electric mode and in battery mode.
- 3.9 The machine room layout of various equipments shall be designed by the supplier. Further the CG should be balanced. Firm shall ensure the CG of the locomotive along with the CG of each equipment. Further firm shall ensure the weight balancing with weight distribution of all equipments inside the locomotive.

3.10 Battery for Traction & Auxiliary purpose

- 3.10.1 **Type of battery:** ACC battery meeting the performance requirement should be used. Design approval should be taken from purchaser during the design approval stage. The battery should be able to deliver the required energy requirement so that load of 5900T shall be started on level gradient and should continue to haul the load with speed of 30kmph for duration upto 60 minutes.
- 3.10.2 The responsibility for safe operation of battery with reliability shall lie with the supplier. Suitable battery management system (BMS) with fail safe protection system for the on-board battery bank and its charger should be adopted for reliable operation of the battery.
- 3.10.3 It should be properly mounted in the locomotive with proper care of its size, weight and cooling arrangement to withstand the shock and vibration.
- 3.11 **DC-DC Converter for traction/Auxiliary battery:** DC-DC Converter shall also be able to operate from power generated during regenerative braking while working under battery mode apart from normal operation on 25kV OHE. The DC-DC Converter shall be rated such that it can charge the battery from fully discharged state to fully charged state within 5 hours.

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3.12 **Battery for Control Electronics:** There should be separate Ni-Cd type 199Ah/C5A or other type of ACC battery for control electronics of the locomotive.

3.13 Determination of battery power, Ampere hour, weight & space requirement to haul a train of 5900t load on level gradient by WAG9H locomotive at 30kmph speed is given below. This stipulated requirement is only for guidance purpose. Supplier shall do the necessary calculation to determine the battery capacity to meet the performance requirement stipulated in this specification.

Rail horse power requirement (kW)	707
Auxiliary load (kW)	150
Total Power requirement for Traction & Auxiliary (kW)	857
Time for operation on battery (Hour)	1
kWh	857
Considering DC link voltage (Volt)	2800
Ah	306
Battery voltage(Volt)	12.8
Ah of battery	300
No. of battery required to match with DC link voltage	219
No. of parallel path to achieve required Ah	1
Total no of battery	223
L x B x H of battery (mm x mm x mm)	522,267,220
Volume of battery (m ³)	0.031
Total space required (m ³)	6.91
Wt of battery (kg)	34.36
Total Wt of battery (tonne)	7.67

Note: Following auxiliaries will not run during battery mode.

1. TFP Oil Pump= 2x4.7=9.4kW
2. One Compressor = 15kW
3. Scavenger Blower for OCB+TMB=2x3=6kW
4. No requirement of Machine Room Blower & its Scavenger running in battery Mode.

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3.14 Detail of particulars of lithium iron phosphate (LiFePO₄) battery used for aforesaid calculation is as under:-

- Lithium iron phosphate (LiFePO₄) battery provides 100% of its rated capacity.
- LiFePO₄ batteries are lighter, take less space and last longer.
- Require no maintenance and they have up to 10x longer life.
- LiFePO₄ Batteries use the safest and mostly has a built-in Battery Management System (BMS).
- Specification: Voltage: 12.8V, Amp Hours: 300Ah considered for 30kmph
- Dimension & Weight: L x B x H : 522mm x 267mm x 220mm, Weight: 34.36 kg

4.0 Design Parameters

Sharpest curve to be negotiated Single unit without buffer Double unit with buffer	174m radius and 1 in 8½ turnout in either Direction
Locomotive weight	132T (Max.)
Nominal Axle Load	22.0T (Max.)
Wheel diameter (mm)	1092mm (New) 1016mm (Condemning)
Gear ratio	1:5.133
Maximum operating Speed at level gradient with train load of 5900t - Battery Traction Mode - Electric Traction Mode	30 kmph 100kmph
Tractive effort Vs Speed characteristics	RDSO graph See Annexure-III
Starting Tractive Effort	OHE Mode: Starting Tractive Effort under dry rail conditions shall not be less than 500kN Battery Mode: Starting Tractive Effort under dry rail conditions shall not be less than 288kN
Installed power under standard conditions in	857 kWh @ 2800VDC (to achieve a speed of

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Battery Traction Mode	30kmph for 1 hr)
Installed power under standard conditions in Electric Traction Mode Power to the wheels (Including Auxiliary Power)	6000HP
Installed power under standard conditions in Battery Mode Power to the wheels (Including Auxiliary Power)	1140 HP

5.0 EXTENT OF MODIFICATION

5.1 General Arrangement of Hybrid Electric Locomotive

Existing design of WAG9H locomotive shall be suitably modified for Hybrid mode working with a new General Arrangement, duly incorporating the proposed changes. Effort shall be made for fitment of battery mode equipments in existing / being manufactured loco without major layout changes of existing / being manufactured locomotives & the general arrangement with existing Traction converter / Auxiliary converter is shown in Annexure-I for guidance purpose.

5.2 Power & Auxiliary Circuit of Hybrid Electric Locomotive with traction converter / auxiliary converter

The operation, control and performance of the locomotive in the electric mode are unchanged. In Battery mode, the power circuitry remains the same in principle; the Battery is taking the place of the transformer & battery supply is being fed at DC link. The Power & Auxiliary Circuit of Hybrid Electric Locomotive with existing traction converter / auxiliary converter may be followed as given in Fig.1. In this scheme, two DC-DC converter (with one isolated) in compact design will take the power from the DC-link of the traction converter for traction and auxiliary battery charging. Isolated DC-DC converter to be utilized for auxiliary battery charging.

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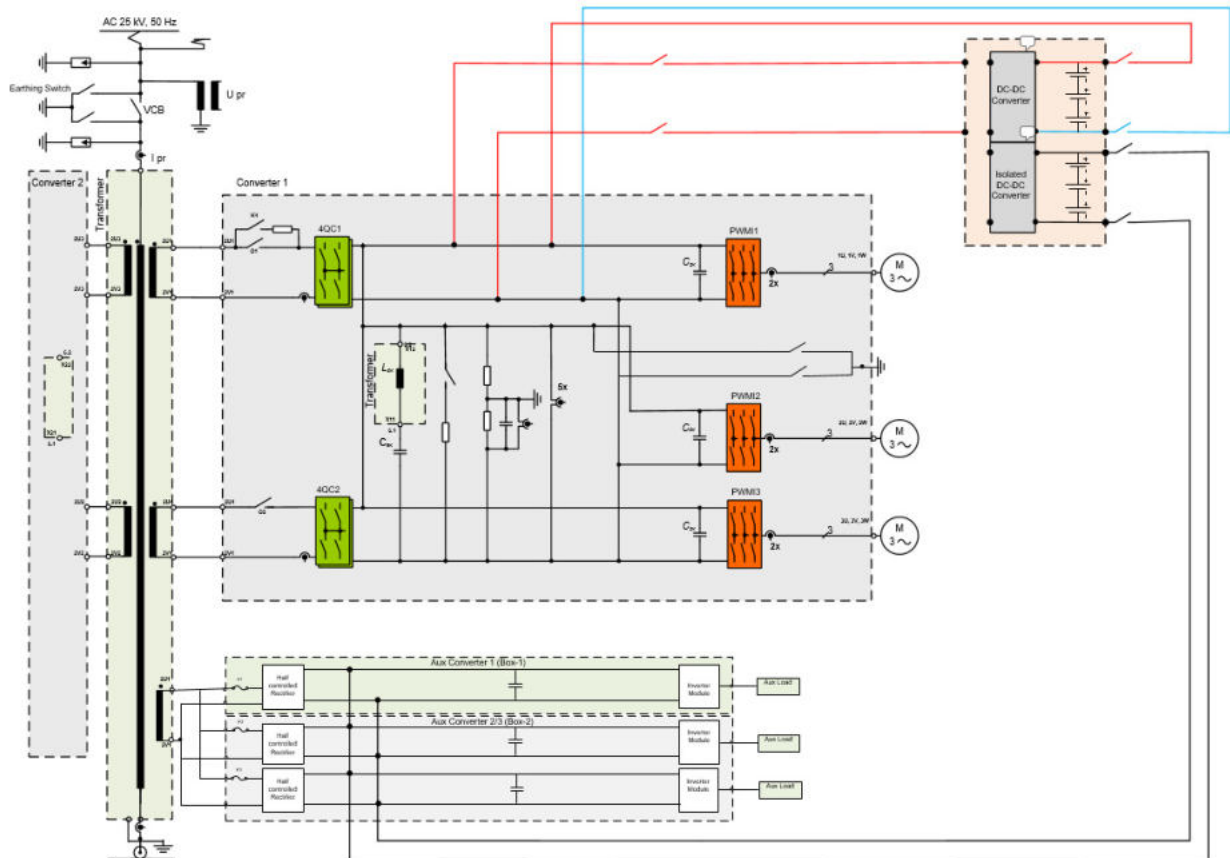


Fig.1 Traction & Auxiliary Circuit of HEL with traction converter / auxiliary converter

6. Mechanical Designs

The mechanical design of HEL will generally remain same as that of base line loco i.e. WAG9H. The general arrangement and equipment layout of the locomotive shall be jointly worked out by RDSO, Production Units and the firm (supplying the Battery mode equipments). The underframe / superstructure will be modified as per final layout of locomotive.

7. Description of additional equipments to be installed & interfaced:

7.1 Advance Chemistry Cell Battery (Traction & Auxiliary) set: 857 kWh, 2800V DC.

7.2 The existing separate Traction & Auxiliary convertor shall be used. The rating particulars shall be as under:

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DC link Voltage	2800V
Output Voltage line to line	2180V
Power Rating to be handled	2x2250kW which includes the power requirement of Auxiliary supplies.

8. Dimensions & environmental conditions

- 8.1 HEL dimensions and profile shall within or fully conform to IRSOD 1D-clearance diagram latest revision.
- 8.2 The Climatic and environmental conditions to be considered are as under

Atmospheric temperature	Maximum temperature of metallic surface under the Sun: 75 degree Celsius and in shade: 55 degree Celsius Minimum temperature: - 10 degree Celsius (Also snow fall in certain areas during winter season)
Humidity	100% saturation during rainy season
Reference site conditions	i) Ambient temperature: -10 °C to 55 °C ii) Humidity: 100% iii) Altitude: 1776 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.

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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.
Wind speed	High wind speed in certain areas, with wind pressure reaching 150 kg/m ² .
Electromagnetic pollution	High degree of electromagnetic pollution is anticipated in locomotive machine room/HT & LT compartment, where the equipment shall be mounted. Necessary precaution shall be taken in this regard. The system shall be interference free from the communication system between the Guard-Driver-Control and Public address system. The system should be tested as per IEC 61000 for Electro Magnetic Compatibility.
Vibration	The system shall be designed to withstand the vibrations and shock encountered in service satisfactorily as specified in IEC 1287 and 60571 publications for the electronic equipments used on Rail Vehicle and relevant IECs as applicable to other equipment.

9. Weight Calculation for Proposed Hybrid Electric Locomotive (HEL)

As per the layout given in Annexure-I, the total weight of the locomotive shall be less or equal to 132 t which will give maximum axle load of 22.0 t. Brief calculation of additional weight on account of HEL and reduction in weight is given in Annexure-II.

10. Simulated Performance Curve of Hybrid Electric Locomotive (HEL)

The hauling capability of proposed HEL on level gradient is indicated in Annexure-III in both mode of operation.

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11. Development and Design clearance of Hybrid Electric Locomotive (HEL)

The designs of integration kit including the details of additional and uncommon items along with weight and envelope size required for building Hybrid Electric Locomotive (HEL) on WAG9H platform shall be furnished for design clearance of PUs/RDSO before the successful tenderer start manufacturing of the items. These items shall be designed / manufactured and supplied as an integration kit. The integration kit shall consist of all the uncommon and additional item irrespective whether indicated in the specification or not. The firm shall work jointly for development of GA and other changes required in consultation with PUs/RDSO.

12. Inspection

Inspection at various stages of locomotive manufacture including final inspection shall be done by PUs. Necessary inspection plan will be jointly worked out by PUs and RDSO.

13. Service Trials:

The Hybrid Electric Locomotives shall also be evaluated during operation under actual load conditions under 25kV AC OHE and Battery Mode. These shall be termed as "Service/Field Trials". Apart from checking on repeatability of the operational performance under different conditions of track, OHE, signaling systems etc. as well as under different conditions of wear and tear on the locomotive itself these tests will also be used to throw light on the maintainability, accessibility, reliability and such other aspects which have been mentioned in this specification. Electric Hybrid Locomotives shall be subjected to service/field trials on IR for at least one month. The tenderer shall depute a team of engineers for commissioning, testing and field trials of the locomotive and its equipment in service. The tenderer's representative shall associate in field trials with purchaser.

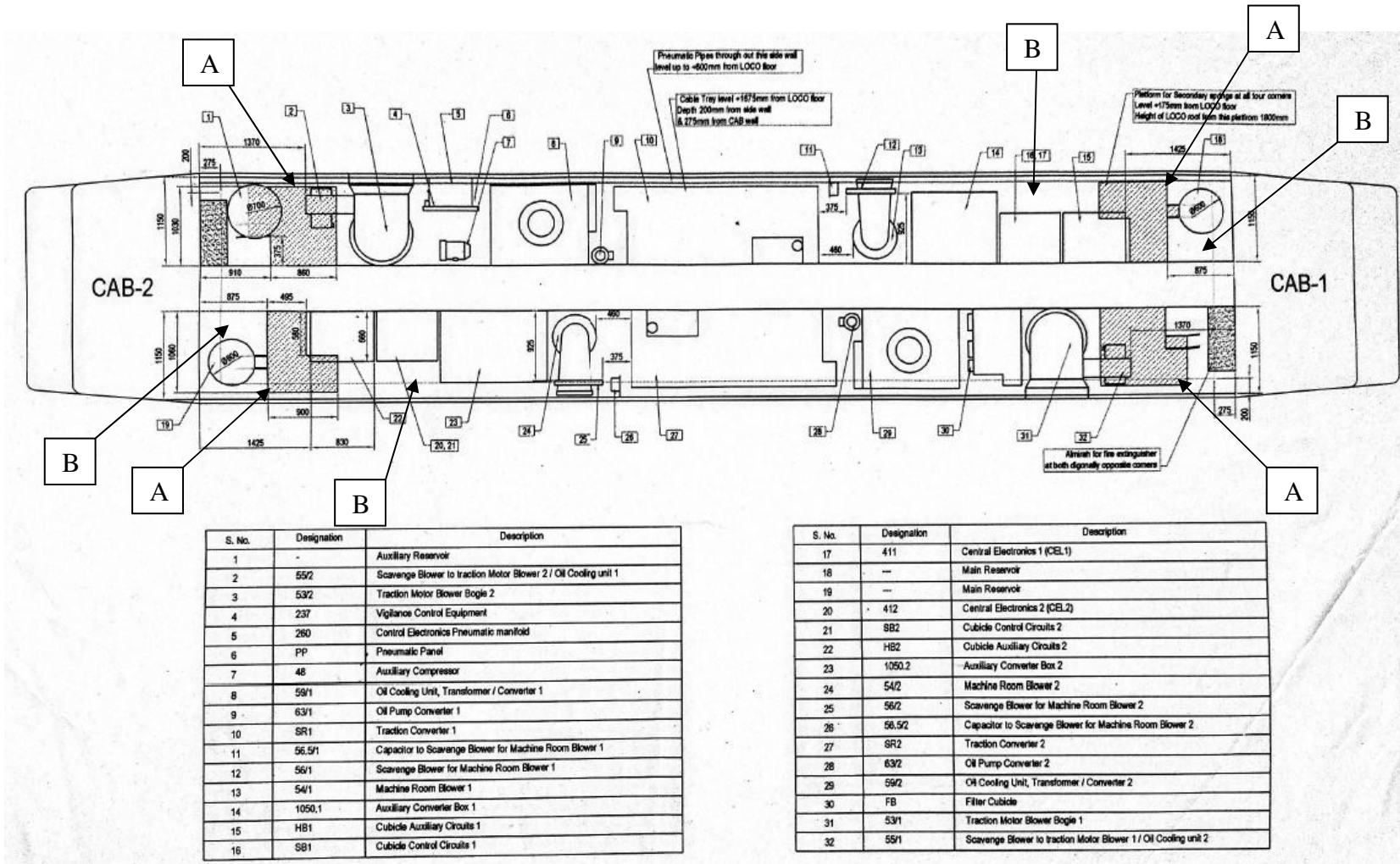
Modifications found necessary as a result of the tests/trials shall be incorporated by the Supplier at his own cost in the locomotives in a manner approved by purchaser. Drawings incorporating the modifications found necessary, as a result of tests and trials, shall be submitted to purchaser for final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

The system should be capable of continuous operation during varying atmospheric and climatic condition.

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Annexure-I

Tentative General Arrangement of Proposed Hybrid Electric Locomotive on WAG9H platform with existing Traction/Auxiliary Converter



Note: (i) A stands for; Tentative location of Traction Battery in place of ballast weight.
 (ii) B stands for; Tentative location of DC-DC converter

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Annexure-II**Tentative Weight reduction/addition in the proposed Hybrid Electric Loco on WAG9H platform with axle load within permissible limit of 22T**

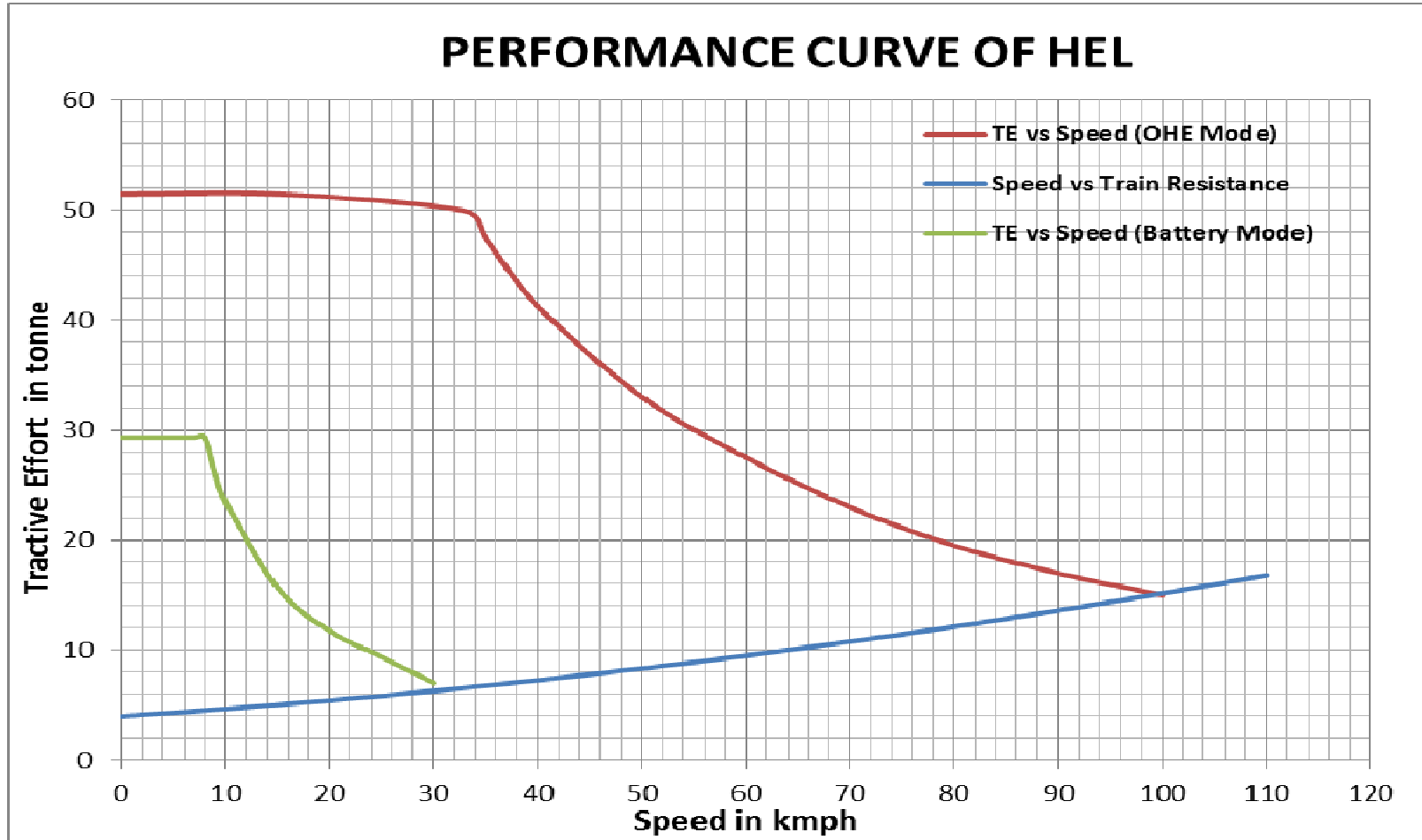
- The equipments will be placed generally in line with Tentative Layout (Annexure-I). The Additional weight for Battery mode will be compensated by removing the dead weight used in WAG9H i.e. 9t to keep the axle load within permissible limit of 22T.

SN	Item Description	Likely Weight Addition(kg)	Likely Weight Reduction(kg)	Net Change (kg)
1.	Battery set (complete), 857 kWh	7670	-	7670
2.	Dead weight		9000	-9000
3.	Modular for battery set, DC-DC Converter & its sub-assembly	1330		1330
Total increase in weight(kg)				0
Net Increase in Axle load(kg)				0
Existing Axle load of WAG9H(t) with ballast weight				22.0
Axle load of Proposed Hybrid Electric Loco(t)				22.0

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Annexure-III

Tractive effort Vs Speed characteristics of Hybrid Electric Locomotive (HEL)



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