सत्यमेव जयते
Goverment Of India

भारत सरकार
रेल मंत्रालय

Technical Specification

For

Hydrogen Fuel cell based DPRS with regenerative braking system Broad Gauge 1200 KW DEMU

Specification No.R2/347/Fuel Cell-1
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Abbreviations

AAR	Association of American Rail-roads
APC	Auxiliary Power converter
BG	Broad Gauge (1676 mm)
BOP	Balance of Plant
CAMC	Comprehensive Annual Maintenance Contract
CCOE	Chief Controller of Explosive
CRRM	Credit for Released Material
CRS	Commission of Railway Safety
DEMU/DMU	Diesel Electric Multiple Unit (1600 hp)
DOD	Depth of Discharge
DPC	Driving Power Car
DPRS	Distributed Power Rolling stock
EMS	Energy management Strategy
EP	Electro Pneumatic
FC	Fuel Cell
FEA	Finite Element Analysis
GPS	Global Positing system
HMI/MMI	Human Machine Interface/Man Machine Interface
HP	Horse Power (Metric)
IR	Indian Railways
IEC	International Electro-technical Commission
IGBT	Insulated gate bipolar transistor
IRS	Indian Railway Standard
IS	Indian Standard
IRSOD	Indian Railways Schedule of Dimensions
MMD	Maximum Moving Dimension
NR	Northern Railway
PC	Power car
PEMFC	Proton Exchange membrane Fuel cell
PRD	Pressure relief Device
PU	Production Unit
QA/QAP	Quality Assurance/Quality Assurance Programme
RDSO	Research Designs and Standards Organization
SOC	State of charge
T	Tonnes (Metric)
TC	Trailing Car
TCV	Trailing Car Vendor
UIC	Union International Des Chemis defer (International Union of Railways)
VCU	Vehicle Control Unit
WTB	Wired Train Bus
ZR	Zonal Railways

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1.0 Purpose

To develop fuel cell and battery based hybrid power train along with associated control and suitably designed Energy Management Strategy (EMS) and storage module for retrofitment on 1600 HP DEMU.

2.0 Background

The hydrogen fuel cell based rail propulsion technologies powered by PEMFC (Proton exchange membrane based Fuel Cell) along with a suitably sized battery bank are being tried out globally for powering railroad vehicles. Elimination of fossil fuel and very low emissions are inherent advantages of such a rolling stock. Indian Railways plans to convert the existing 1600 HP DEMU 10 car configuration (2 DPC's + 8 TC's) into hybrid fuel cell and battery based Distributed Power Rolling Stock (DPRS) with regenerative braking.

Following documents/drawings/specifications may be referred for technical guidance-

S.No.	Title of Document	Document/Drawing/Specification No.
1.	Rake configuration for 1600 HP AC-AC DEMU	ICF Drawing No. DMU/DPC/SS-9-0-001, DMU/TC/SS-9-0-001
2.	Installation of under frame equipments for 1600 HP AC-AC DEMU	ICF Drawing No.:DMU/DPC/SS-9-0-003
3.	Specification for 3 phase AC-AC transmission system and associated control equipment for 1600 HP DEMU	Specification no. MP.0.24.00.45 (Rev.03) of January 2017 issued by RDSO
4.	Maintenance manual of 1600 HP DEMU	Document no. 1.00/03-20/1 dated 01.03.2019 and 1.00/03-20/2 dated 01.03.2019 issued by CAMTECH
5.	Section details of Sonepat-Jind	Drawing no.: DY.CE/C/CSB PLAN NO. IS-741/COMP/GHNA-SNP/2015.SH.2

3.0 Design requirements:

Hydrogen fuel cell based power stacks (Primary energy source PEMFC) along with the complete associated support and auxiliary systems like energy storage module (Secondary energy source i.e. Battery Bank), traction converter/Inverter, hydrogen storage module, Hydrogen Safety equipments, Fuel cell control system, propulsion control system, air handling unit, heat exchangers etc. (i.e. Balance of Plant) suitable for supplying power for the complete Driving Cycle and meeting the average and peak power demand during the cycle based on a suitably designed EMS (Energy Management Strategy) for peak total power rating of 1200 KW shall be retrofitted on existing DEMU 1600 HP platform (ICF) having nominal axle load of 20.32 Tonnes (Metric) for DPC (as per ICF drawing no. DMU/DPC/SS-9-0-001).

Indicative rating of power train components based on operational requirement of 1600 HP DEMU can be taken as:

- Primary Energy Source: PEMFC of 800 KW Hydrogen fuel cell based power stacks preferably in the multiples of 100/150/200 KW)
- Secondary energy source: Battery bank of 330 to 380 KWH with power rating of 400 KW

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Optimization of power train components in terms of final rating to meet the actual drive cycle requirement (both peak and average) will have to done by bidder as per indicative drive cycle (Annexure-II). Power train should be so designed that it has minimal weight and space implications on the car body of the vehicle and shall not exceed the structural strength limits of the car body. Optimization should include all accessories and balance of plant (BOP) in compliance with axle load limits and other structural strength requirement of car body. The Energy management strategy (EMS) should be so designed that the difference between the State of Charge (SOC) of the battery from start of cycle to at the end of cycle should be minimum. The Depth of Discharge (DOD) of the battery should be upto 60% i.e. State of Charge (SOC) should not go below 40% during the drive cycle. However, the optimum level of DOD can be decided by the tenderer duly conforming the SOC stipulation.

The Hydrogen Fuel Cell Retrofitment kit along with the Balance of Plant and Energy Storage and Hydrogen Storage modules will replace the existing power-train items as indicated in the drawing at Annexure-III. Indicative list of items to be removed from DEMU is mentioned below -

- Engine
- Alternator
- Radiator
- Batteries
- Fuel tank etc.
- Invertors/Convertors (May use existing/modify design suitably or replace with new)
- Traction Motors (May use existing/modify design suitably or replace with new AC Traction Motors)
- Vehicle Control Unit (VCU) (May use existing/modify design suitably or replace with new)
- Any other items mutually agreed

Conformance to following Boundary Conditions while designing retro-fitment kit (retro-fitment scheme) has to be ensured by bidder:

a. Existing DEMU DPC Bogies shall not be altered/changed. However, existing traction motors may be used, modified suitably or replaced with new design AC Traction motors for satisfactory functioning of the system and should match the existing Tractive effort - Speed (T-S) curve (refer Specification no. MP.0.24.00.45 (Rev.03) of January 2017 issued by RDSO) and Dynamic braking effort-Speed curve (attached as Annexure-VII) characteristics as far as possible, keeping outer envelope, weight and mountings of Traction motors similar with the existing traction motors of 1600 HP DEMU.
b. Existing Traction convertors/Invertors may be used, modified design suitably or replaced with new traction convertors/Invertors for satisfactory functioning of the system.
c. Car body to bogie interface shall not be altered/changed.
d. The total space envelope that will be available for retrofitment in the existing engine room and passenger area is indicated in the drawing at Annexure-IV. The existing power-train equipment shall be replaced by the Fuel Cell power-train modules keeping axle load within limits. The layout of the Fuel Cell Power-Train modules (including Energy Storage) should

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be suitably designed so as not to exceed the specified axle load limits as mentioned in para 3.0 and MMD as per enclosed diagram (Annexure-I).

e. Axle load of DEMU DPC with the retro-fitted equipments shall not exceed 20.32 Tonnes (metric).
f. The layout shall be so designed that it should not adversely disturb the existing center of gravity of the retrofitted DEMU as mentioned under para 4.14. Weight balancing of the retrofitted DEMU shall be done as mentioned in para 4.14 and shall be in scope of successful bidder.
g. Mounting of equipment/sub-assemblies shall not create infringement with IRSOD 1D diagram of Indian Railways. (Indian Railways Schedule of Dimensions For Broad Gauge Network with latest amendments)(attached as Annexure- I)
h. Peak Power rating of the Fuel cell based DEMU DPC shall be 1200 KW for each basic unit of 05 coaches (1DPC + 4TC). The typical driving cycle (indicative) of 1600 HP DEMU presently operating in Sonepat-Jind section of Northern Railway has been selected for this project is enclosed as Annexure-II and may be confirmed from consignee.
i. Space available onboard/under slung and top/roof of DPC can be utilized for mounting of power train components, auxiliary equipments and hydrogen cylinders/modules etc. in such a way that it should comply with all safety regulations guidelines/certifications/conventions etc. and shall not compromise the axle load limits and safety of passengers.
j. Suitable Hydrogen fuel storage system onboard (in pallets/modules) will be a part of the retro-fitment kit. The storage capacity for onboard storage of Hydrogen has to suffice for Four Driving-Cycles (2 driving cycles of each type) enclosed with this document (2 round trips). The sizing of components should have adequate built-in capacity margins to take care of normal variations in the driving cycle due to day-to-day operational constraints. Hydrogen fuel storage (in pallets/modules) should be designed for 20% extra capacity as additional margin over and above the requirement of the Hydrogen.
k. The proposed Retro-fitment kit and Retro-fitment scheme shall have to comply with the existing legal and safety regulations and undergo certifications applicable in India for application in service. It will be the responsibility of the bidder to ensure compliance to all legal and statutory requirements associated with hydrogen fuel cell – battery based hybrid power train and hydrogen storage system offered for this project. Any other additional standard specifications/regulatory guidelines/established convention/certification requirement etc. which is considered applicable/relevant for this project shall also be complied by the bidder and compliance documents submitted prior to commissioning.
l. The system should be so designed that all the controllers of the systems/sub-systems of retrofitted DEMU shall be interfaced with VCU besides existing/retained system required for safe operation of the train.
m. Air brake/EP Brake system shall continue without any modification. Minor modification in layout of piping, if needed, will be done with prior written permission of IR/RDSO.
n. Existing DEMU DPC has no provision of regenerative braking system, however, retrofitted DEMU DPC shall have provision of regenerative braking with all necessary controls/interfacing etc. to utilize the maximum energy during braking.
o. In built redundancy in the design of fuel cell based propulsion architecture shall be such that in case of failure of one or more fuel cell stack, propulsion with limited capacity/battery bank power stays operational as back-up mode during train service.
p. Fuel cell and its balance of plant, batteries and convertor/invertors should be of proven technology and from reliable sources.

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q. Proper electrical isolation for low voltage signals and high voltage power supplies shall be provided. Proper distances between high and low voltage circuits as well as to the ground shall be maintained.
r. Where no tolerances are prescribed, nominal variation of ±5% may be considered wherever applicable.
s. The firm representative should visit the nearest IR facility handling 1600 HP DEMU to acquaint himself with the existing system for better understanding.

4.0 Other functional requirements

4.1 Technical design features of all the major equipment such as fuel cell stacks, onboard hydrogen storage system (in pallets/modules), on-ground hydrogen storage, battery, converters/inverters and controls etc. shall be governed by the relevant IEC/International standards. However any other additional standard specifications/regulatory guidelines/established convention/certification requirement etc. which is considered applicable/relevant for this project at the time of commissioning shall also be complied by the bidder.

4.2 Direct hydrogen based fuel cell stack(s) shall be used.

4.3 The fuel cell stack (PEMFC)performance parameters are as under. However better designs/configuration(s) will be considered for this application:

S.No.	Parameters	Value
1.	Efficiency @rated power	50% or better
2.	Operating temperature	-30^{0}C to 55^{0}C
3.	Emission	Negligible emissions (PM, NOx, SOx, CO or CO_2)

Note: (a) Bidder shall submit the test certificate complying above parameters with the offer.

(b) This technology is being introduced first time by Indian Railways with limited experience and field data. Rated life of fuel cell as available in public domain indicate wide variance in the range of 10000 hrs to 30000 hrs. In order to ensure consistent performance of fuel cell power train for a reasonable period in service for this pilot project, benchmarked rated performance is being specified as 05 years at the rated efficiency delivering performance parameters to meet the driving cycle requirement (as per Annexure II) for 02 round trips (04 driving cycle) per day for a period of 05 years.

(c) The financial viability of the offers and their inter-se ranking while deciding the most suitable options will be based on the cost of ownership of the equipment i.e. capital cost of the procurement and subsequent maintenance cost upto the 05 years (02 years warranty + 03 years CAMC). Consignee shall consider necessary credit for released materials (CRRM) in commercial bid evaluation for key sub-assemblies identified under para 3.0.

4.4 The system shall produce clean DC power with a low thermal and acoustic signature. The output of the fuel cell stack will be routed through IGBT based converters, DC bus to drive 3-phase AC traction motors.

4.5 The system shall be compact with modular construction.

4.6 The system shall be so designed that the acceleration of the retrofitted DEMU DPC shall not be less than the existing DEMU DPC.

4.7 It shall incorporate state of the art technology including its own humidification and hydrogen recirculation systems.

4.8 The cooling system shall provide constant airflow to fuel cell system to preclude confinement of accidentally leaked hydrogen.

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4.9 All service points shall be located on the perimeter of the fuel cell power plant to allow full service without module removal.

4.10 The layout shall preferably allow symmetric piping of air and coolant to all fuel cell stack modules, and shall result in closely balanced flow for the air and coolant systems. The layout shall be suitably designed keeping in view that the piping in the fuel cell should not be intercoiled and easily accessible for maintenance purpose"

4.11 The hydrogen storage units (onboard) shall be of adequate pressure rating (350 bar) and shall comply with the relevant international standards related to vehicle functional safety, hydrogen safety and protection of persons against electric shocks mentioned under para 7.0. However any other additional standard specifications/regulatory guidelines/established convention/certification requirement etc. which is considered applicable/relevant for this project shall also to be complied by the bidder prior to commissioning.

4.12 Suitable layout design incorporating hydrogen cylinders (fitted in pallets/modules) in retrofitted DEMU abiding safety regulations etc. as applicable shall be submitted by the bidder.

a. The design of Fuel cell based DEMU (10 Car configurations consist of 02 DPC+08 TC) should facilitate re-filling of empty Hydrogen cylinders/cartridge (fitted in pallets/modules)in in-situ conditions on-board using a suitably designed Hydrogen refilling system within a reasonable time not exceeding 60 minutes.

b. Manual replacement of hydrogen cylinders/cartridge (fitted in pallets/modules) shall be allowed for maintenance purpose only.

4.13 **Remote diagnostics:**

Hydrogen fuel cell based hybrid power train shall be equipped with remote diagnostics wherein critical health data and other important parameters along with GPS location information should be available to maintenance depot. It is required to transfer the data from Hydrogen fuel cell based hybrid power train's microprocessor control system at regular intervals to a central database using commercially available networks.

Parameters need to be recorded for efficient working of the system that include(but are not limited to) fuel cell and its balance of plant, battery health, braking system efficiency, hydrogen storage, propulsion system, electrical control system etc. shall be taken up for monitoring. The details of parameters to be monitored for above systems are mentioned in Annexure-VI. In addition, consignee may specify any additional parameters related to system reliability and safety in Annexure-VI.

An online monitoring system shall be established in the maintenance depot for monitoring of parameters of retrofitted DEMU for which follow up protocol should be advised.

In case of emergency, SMS alerts to at least four Railway's nominated members and nominated Control Rooms shall be sent automatically by the system.

4.14 **Operating requirements:**

Section details of Sonepat-Jind	May kindly refer Drawing no.: DY.CE/C/CSB PLAN No. IS-741/COMP/GHNA-SNP/2015.SH.2

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Center of Gravity (C.G.)	Maximum C.G. height above Rail level for existing 1600 HP DEMU DPC under gross load condition is 1434.7mm
Weight balancing	Equipment distribution should be such that total unbalanced load in gross and tare weight should be within permissible limits of 1500 Kg in longitudinal and 500 Kg in transverse direction of the vehicle.
DPC DMU 1600 hp weight Nominal Axle Load	Not exceeding 80.785 t Not exceeding 20.32 t
Operating Speed. Test speed	110 kmph 120 kmph

5.0 Scope of work:

The scope will cover Design, supply, certifications/safety & regulatory compliances, retrofitment, testing & validation which includes 'Factory Sub-system level test/ Drive train Integration test', System Prove Out Test, Performance Test Runs and Field Trials of fuel cell & battery based power stack modules, hydrogen storage onboard (fitted in pallets/modules)/on-ground hydrogen storage, power electronics/controls & associated equipments including necessary engineering & supervision work and compliance with all safety norms for hydrogen uses for retrofitment of 1600 HP broad gauge DEMU DPC. The interfacing of the Fuel Cell Stack Controller with the Vehicle Control Unit (VCU)/ Propulsion Control System and existing safety operational features of the train shall also be a part of the Scope of work.

Any structural change which will be part of retrofitment will have to be structurally validated for strength and durability by the bidder.

It shall be the responsibility of the successful bidder to deploy competent personnel for handling this project to meet safety and maintenance requirement during the running of train under warranty and CAMC.

Infrastructure facilities developed for hydrogen storage, refilling of hydrogen cylinders, inspection and testing (para-18.0) shall become the sole property of Indian Railways.

An indicative list of the equipment covered in scope of supply is as under, however, any other component / Assembly / Software/ Hardware etc., that is required for proper and safe functioning of the retrofitted equipments, shall be supplied as a part of scope of work and shall be the responsibility of the bidder.

i. Type-IV Hydrogen storage tank(s)/cylinder(s)fitted in pallets/modules
ii. Piping, safety/ sensing and controlling devices for hydrogen filling and storage
iii. All types of Cables (including communication cables)
iv. Hydrogen Fuel cell stack/modules
v. Air delivery, and Cooling Systems

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vi. Battery Modules
vii. Gauges & Fittings
viii. Auxiliary power systems
ix. Regenerative braking system with necessary controls/interfacing
x. Vehicle Control Unit (VCU)(May use existing/modify design suitably or replace with new VCU)
xi. AC Traction Motors (May use existing/modify design suitably or replace with new AC Traction Motors)
xii. Traction convertors/Invertors(May use existing/modify design suitably or replace with new traction convertors/invertors)
xiii. Remote diagnostic system (including online monitoring system) to be setup in maintenance depot with SMS alert to atleast four Railway nominated members.
xiv. On ground infrastructure for Hydrogen storage (in compressed gaseous form) and refilling unit for onboard hydrogen refueling
xv. Suitable hydrogen gas leakage detection system and isolation plan shall be provided for on board hydrogen cylinders/modules and on-ground hydrogen storage infrastructure
xvi. Automatic fire detection and alarm system for retrofitted DEMU and on-ground hydrogen storage infrastructure.
xvii. Suitable fire extinguishers in adequate quantity shall be provided in the retrofitted DEMU and for on-ground hydrogen storage infrastructure.
xviii. Testing infrastructure/facilities required as per para 18.0 of this specification.
xix. Adequate quantity of maintenance spares, tools, consumables if any.

5.1 On ground hydrogen Infrastructure and supply:

(i) Hydrogen gas for inspection and testing of hydrogen fuel cell based hybrid power train shall be supplied by successful bidder as per requirement mentioned under para 18.0. Payment shall done on actual basis against invoices.
(ii) Successful bidder shall provide the Hydrogen storage (in compressed gaseous form) facility on ground at nominated area as decided by consignee to store minimum 3000 kg hydrogen either in single or in multiple tanks to meet the operational requirement for refilling the onboard hydrogen cylinders/modules.
(iii) Successful Bidder shall provide the provision in the design to facilitate manual replacement of hydrogen cartridge/cylinders (fitted in pallets/modules) for maintenance purpose only.
(iv) The infrastructure developed for refilling of hydrogen using standard arrangement for refilling onboard hydrogen cylinders/modules from stationary/ mobile/line-side hydrogen storage tanks/installation will be in the scope of successful bidder.
(v) The fuelling dispensers shall have provision of automatic cut-off to avoid wastages/spillage or undesirable vent off.

5.2 Safety Audit:

Successful bidder shall get the third party safety audit of hydrogen fuel cell based DPRS and the hydrogen storage facilities done by a reputed national/International agency which have experience in performing the safety audits of hydrogen storage and hydrogen fuel cell based systems. The selection of the firm for performing the safety audit shall be done with the approval of consignee. The safety audit certification shall be done before start of field trials.

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5.3 Successful Bidder has the responsibility of obtaining regulatory/safety compliance certification from concerned regulatory authorities in India both for hydrogen transportation and hydrogen storage in the form of mobile dispensing unit/any other suitable hydrogen storage facility at nominated IR facilities. Indian Railways will assist successful bidder by providing land, power, illumination, water etc. necessary for setting up the mobile dispensing unit or any other suitable hydrogen storage facility / installation at nominated yards/platforms/depots.

6.0 Environmental conditions

Fuel cell based DEMU DPC shall be required to work continuously on the designed Energy Management Strategy (EMS) under following atmospheric conditions:

Maximum temperature (Atmospheric)for DEMU and for on-ground hydrogen storage	(i) 55 °C (under sun). (ii) 47 °C (in shade) (Temperature inside DEMU DPC may reach 55 °C.)
Humidity	90 % (Up to 100% during rainy season.)
Altitude	Refer Annexure-II
Operation in rainy season	The DEMU DPC shall be designed to permit it's running at 5 Km/h in a flood water level of 10.2 cm above the rail level.
Dust	Extremely dusty and desert terrain in certain areas. The dust content in air may reach as high a value as 1.6 mg / m^3.
Atmospheric conditions in coastal areas in humidity salt laden and corrosive atmosphere	All the equipment shall be designed to work in coastal areas in humidity salt laden and corrosive atmosphere. (a) Maximum PH value : 8.5 (b) Sulphate: 7 *mg* / litre. (c) Max. concentration of chlorine : 6 mg / litre (d) Maximum conductivity : 130 micro siemens/cm

7.0 National /International standards

The retrofitted equipments should conform to the relevant clauses of the applicable standards. However any other additional standard specifications/regulatory guidelines/established convention/certification requirement etc. which is considered applicable/relevant for this project will also to be complied with by the bidder and submit the details with the offer. Indicative list of National/International standards is given below-

SN	Standard No.	Title
1	ISO 23273:2013 Fuel Cell road vehicles- safety specifications – Part-2	Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen
2	IEC 62282-3-100:2019 Fuel cell technologies – Part 3-100	Stationary fuel cell power systems – Safety
3	EC79/2009 Type approval of hydrogen	powered motor vehicles
4	IEC 62282-3-100:2019	(5.14 Rain test)
5	ISO 23828:2013	Fuel cell road vehicles-Energy consumption measurement- Vehicles fuelled with compressed hydrogen

6	SAE J2578	Recommended practice for General Fuel Cell Vehicle Safety
7	GTR-13	'Global Technical Regulations on Hydrogen and Fuel Cell vehicle'
8	ISO 14687	Hydrogen fuel quality-Product specification
9	ISO 17268:2020	Gaseous hydrogen land vehicle refuelling connection devices
10	EN 17339:2020	Transportable gas cylinders - Fully wrapped carbon composite cylinders and tubes for hydrogen
11	ISO 6469	Electrically propelled Road Vehicles- safety specifications
12	ISO 6469-1 part-1	onboard rechargeable energy storage system (RESS)
13	ISO 6469-2 part-2	Vehicle operational safety means and protection against failures
14	ISO 6469-3 part-3	Protection of persons against electric shock
15	ISO 6469-4 part-4	Post crash electrical safety requirement
16	BS EN 50343:2014+A1: 2017 Railway application, Rolling stock	Rules for installation of cabling is classified in these ICS categories
17	BS EN 50124-1:2017 Railway applications. Insulation coordination	Basic requirements. Clearances and creepage distances for all electrical and electronic equipment
18	BS EN 60077-1:2017 Railway applications. Electric equipment for rolling stock.	General service condition and general rules
19	BS EN 50155:2017 Railway applications. Rolling Stock.	Electronic equipment
20	IEC 62497-1: 2010 + AMD1:2013 CSV Railway applications. Insulation coordination. Basic requirements.	Clearances and creepage distances for all electrical and electronic equipment
21	IEC-60571 & IEC-61287	System and their mountings shall be designed to withstand vibrations as per IEC-60571& IEC-61287
22	IEC-61373	Railway applications – Rolling stock equipment – Shock and vibration tests
23	EN 45545	Fire safety standard to ensure the safety of people and equipments in Railway application

8.0 Hydrogen onboard storage:

Hydrogen fuel storage (Type-IV cylinders/tanks/Modules) shall use readily available hardware and should comply with all safety regulations / certifications related with hydrogen safety measures. Modules shall be mounted as per approved layout based on center of gravity, weight and unbalanced moment criteria of Railway stock. This storage system shall provide fuel for the requirement as mentioned under **Para-3.0 (j)** of this document. Hydrogen storage should be modular with provision of isolating the hydrogen storage module in case of emergency. Isolation sequencing plan shall be submitted by the successful bidder.

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Indicative design requirement for hydrogen on-board storage is mentioned below, however better design along with additional safety devices may also be considered.

Each hydrogen cylinder/tank shall incorporate an excess flow valve, thermally activated pressure relief devices (PRD), temperature sensor, electronically controlled solenoid valve, and manual shut-off valves. In the event of a line rupture between the tank and distribution manifold, the tank excess-flow valve shall close. In the event of excessive heat caused by battery fire, the thermally activated Pressure Relief Devices (PRD's) shall vent the tank contents through a routed vent line pointing upward and away from the vehicle. The temperature sensors shall be utilized by the control system to regulate refueling speed as well as indicate any over temperature warnings. The electronic solenoid valve shall be normally closed, powered open for run and refueling modes, and closed if a high level system fault is detected.

The module manifolds, each with independent pressure sensors, shall be connected to a primary distribution line that includes an excess-flow valve to control any ruptures in the primary distribution line. The primary distribution line shall connect to the refueling line, and shall then continues to a filter, pressure regulator, additional electronic solenoid valve, pressure sensor, and an additional PRD. The additional solenoid valve shall add a layer of shutdown capability, while the pressure sensor verifies regulator functionality.

An emergency shutoff device shall be located on each side of the DEMU DPC near the driver cab to allow non-operators or refueling personnel to shut down the fuel system. Emergency shut off device should be operated electrically and mechanically for emergency override.

Hydrogen gas leakage detection system and Isolation Plan:

Suitable Hydrogen gas leakage detection system and isolation plan shall be provided for on board hydrogen cylinders/modules and on-ground hydrogen storage infrastructure.

9.0 Power electronics:

In order to effectively use the fuel cell as the prime mover and a battery charging source, the power shall be delivered to the retrofitted DEMU DPC high-voltage bus at the correct power and voltage levels. The system controller shall receive a power set point from the VCU and in turn control the power output from the fuel cell stack and battery bank and accordingly control the operation of Balance of Plant (BOP) as well as the DC/AC traction converter/inverters output to suit the Tractive Efforts-Speed (T-S curve) of traction motors.

10.0 Battery System:

The Lithium ion power batteries shall be used. However, alternate design of batteries may also be accepted based upon performance standpoint (i.e. better Energy and Power density, Life Cycle etc.).

11.0 Driving Cycle:

Driving Cycle for the targeted section on Zonal Railway where DEMU will operate is attached as Annexure-II.

12.0 Fuel Cell based Power-Train Control System & its Integration with Vehicle Control Unit (VCU):

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The operation of all fuel cell subsystems shall be monitored and coordinated by a central control system. The successful bidder shall be responsible for integrating Fuel Cell controller with existing VCU/modified or new VCU including all third party interfaces. The Microprocessor shall monitor and log the critical and important operational Fuel Cell and Battery health related parameters. The information to be displayed to the driver/assistant shall be decided mutually between IR and the Fuel Cell system designer. The bidder can suitably modify the existing VCU or replace with new VCU to make system fully functional by integrating the hydrogen fuel cell, battery, fuel parameters etc. without affecting the existing performance of other functions like, Propulsion Control, APC, traction alternator Voltage and current, Traction convertor, Fault diagnostics and recording, event recorder, display, WTB (Wired train Bus), Adhesion and Wheel Slip Control and auxiliaries etc.

13.0 Mounting and Isolation

Mounting of all fuel cell system modules to the DEMU DPC is of critical importance because DEMU DPC are marshaled in rail yards, which can lead to shock loads up to 10g *('g' being acceleration due to gravity)*. Although they are of short duration, shocks of this magnitude could lead to immediate or fatigued failure of components or mounting structures. To mitigate this harsh environment, each module shall be isolated from the impact loads, this may be effectively done through the use of springs, specifically rubber or synthetic mounts or isolators.

The mounts natural frequency should be well below the possible disturbing frequencies of the system. The isolation system shall also provide proper shock protection in the horizontal, lateral, and vertical directions. The mounting system shall be designed so that it is at the vertical center of gravity, which shall minimize any rocking motion of the power plant and transmit force directly into the mounts. In addition to careful selection of isolation mounts, Finite Element Analysis (FEA) shall be used to validate all structural weldment designs.

All the equipments and their mounting arrangements shall be designed to withstand vibrations and shocks as specified in IEC-61287 titled "Power Convertors installed on board railway Rolling stock" and IEC-60571 titled "Railway applications-Electronic equipment used on rolling stock"(Reference: Specification no.MP.0.2400.45 (Rev.02) of November 2012 for '3phase AC-AC transmission system and associated control equipments for 1600 HP DEMU').

14.0 Control console

The existing HMI *(Driver Desk Interface) shall remain unchanged. However, the PEMFC, Battery and Hydrogen parameters etc. may be incorporated for display on the MMI/HMI display in the existing control console or additional HMI may be provided without affecting the existing safety systems i.e. sanding, VCD, Flasher light, wheel slip relay and it shall be integrated with the existing/modified/new VCU.

15.0 Fire Safety:

The design and manufacturing of hydrogen fuel cell based system shall be in accordance with EN 45545. A reliable Automatic fire detection and alarm system shall be provided, covering necessary equipment in retrofitted DEMU and for on-ground hydrogen storage system.

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Suitable fire extinguishers in adequate quantity shall be provided in the retrofitted DEMU and for on-ground hydrogen storage infrastructure.

16.0 Regenerated Energy:

The system shall be so designed that maximum regenerative energy can be achieved. The simulation study for regenerated energy for running the retrofitted DEMU in the (Sonepat-Jind) section stopping at all stations, round trip shall be done by the bidder. The equipment required to measure the regenerative energy shall be provided by the bidder.

17.0 Responsibility chart:

SN	Activity/Items	Responsibility
1.	Submission of design/drawings and documents as per para 19.0 'documentation'	Successful bidder
2.	Approval of design layout submitted by the bidder	RDSO
3.	Submission of certifications and approvals complying the regulations/conventions/regulatory guidelines etc	Successful bidder
4.	Approval for onboard hydrogen storage for DEMU	National regulator (if formed)/ RDSO
5.	Approval from CCOE for transportation and uses of Hydrogen at 350 bar	Successful bidder
6.	Installation of on-ground hydrogen infrastructure including necessary certifications and approvals complying regulations/conventions etc.	Successful bidder
7.	Hiring of agency for third party safety audit for complete system including hydrogen storage/ supply infrastructure	Successful bidder
8.	Approval of third party safety audit agency	Consignee/~~RDSO~~
9.	Supply as per scope of work	Successful bidder
10.	Nomination/handing over the DEMU for retro fitment	Consignee
11.	Dismantling of existing power train equipments from DEMU	Successful bidder
12.	Structural modification needed in existing DEMU for retro fitment	Successful bidder
13.	Factory Sub-system level test	Successful bidder witnessed by RDSO/Consignee
14.	Drive train Integration test	Successful bidder witnessed by RDSO/Consignee
15.	Installation of Fuel cell based hybrid power train components	Successful bidder
16.	System Prove out test at IR facility	Successful bidder and witnessed by Consignee and RDSO
17.	Performance Test Runs	Successful bidder and witnessed by Consignee and RDSO
18.	Field trials	Successful bidder and witnessed by Consignee

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18.0 Inspection and Testing:

The tenderer must submit details of test plan for the proposed system for each level of testing covered under para 18.1, 18.2, 18.3, 18.4 & 18.5 as per the relevant ISO/IEC/BS EN etc. standards applicable in terms of para no.7 of this specification. However any addition/deletion/modification in the test plan can be considered on mutually agreeable basis. It should prima-facie include the following details-

18.1 Factory Sub-system level test:

Factory acceptance test shall be carried out to check full functionality of the major components of the system i.e. fuel cell and its balance of plant, battery, hydrogen storage on-board/on-ground, traction motors (in case of new supply) , traction invertors/convertors (in case of new supply), VCU (in case of new supply). This Quality Assurance (QA) test shall be done at manufacturing/testing facility of the equipment. These tests shall be witnessed by the RDSO/consignee representatives. The bidder shall submit the QAP (Quality Assurance Programme) for the same. All documentation and factory acceptance test certificate for this stage of testing shall be submitted to the IR before dispatch of material.

18.2 Drive train Integration test:

Drive train integration test shall be carried out to check full functionality of the integrated systems/sub-system to a fully functional level at firm's premises or at any other third party test facility. These tests shall be witnessed by the RDSO/consignee representatives. The bidder shall submit the test plan to consignee for the same.

18.3 System Prove Out Test:

This test will be carried out on the nominated DPC at IR facility for the full proving out of the system. All individually tested sub-systems, as outlined in the para 18.1, are to be integrated in a fully functional manner on nominated DEMU DPC and offered for inspection. The test will be witnessed by the RDSO/Consignee at the premises of IR facility. Prove out test shall be conducted at the nominated unit of Indian Railways premises on the load box, in which all the performance requirements which can be determined in static condition shall be established by the manufacturer particularly the power requirement. Firm has to setup the requisite facilities (like water load box, electric load box etc.) in Railway premises necessary for these tests. The infrastructure facility developed for system prove out testing shall become the property of IR.

18.4 Performance Test Runs:

Performance test runs of hydrogen fuel cell based hybrid power train will be carried out on nominated route (As per Annexure-II) for 05 days and each day will consists of 04 drive cycles (2 round trips).

Performance test runs shall meet the average and peak power demand for a peak power rating of 1200 KW, maintaining battery State of Charge (SOC) as defined in para 3.0 of this specification. During the performance test runs, successful bidder shall arrange instrumentation and record speed, voltage, current and temperature rise of various equipment, fuel consumption, tractive effort, acceleration, deceleration, regeneration energy and any other relevant parameters.

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Test plan for this test shall be decided with mutual consultation with RDSO/Consignee before start of performance test runs. Necessary instrumentation/tools/equipments required for above test shall be supplied by successful bidder.

18.5 Field Trials:

After successful completion of performance test runs and CRS sanction (if required), Fuel Cell based Hybrid Power Train shall be subjected to field trials on Indian Railways for at least 06 months/50000 Kms whichever is later.

The successful bidder shall depute a team of engineers for retroftment, system prove out test (as per para 18.3), performance test runs (as per para 18.4) and field trials (as per para 18.5) of the 'Fuel Cell based Hybrid Power Train' and its equipment in service. The successful bidder shall associates in the field trails jointly with consignee. The successful bidder shall ensure availability of typical tools and spare parts in adequate quantity for field trials.

All the modification required due to defects noticed or design improvement found necessary as a results of the field trials shall be carried out by the successful bidder in the least possible time. Total cost of such modifications/design changes shall be borne by the successful bidder.

19.0 Documentation

19.1 Following documents shall be submitted along with the offer for evaluation-

(i) Functional description of the complete system and sub-systems including salient features and advantages of the offered system
(ii) Detailed analysis including Energy Management Strategy along with supporting design documents and simulation results for optimization of hybrid power train and hydrogen storage module
(iii) Details of the national/international standard complied by each equipment, offered for retrofitment on DEMU DPC and for on-ground hydrogen infrastructure as per para 7.0 of this specification.
(iv) Certificates in compliance to para 4.3 (a)
(v) Lay out and mounting (2D/3D) drawings of all the systems/sub-system offered to retrofit on 1600 HP DEMU DPC
(vi) Fuel cell efficiency curve and applicable national/international procedure for calculating fuel cell efficiency
(vii) Technical data sheet including make, model, ratings, envelop, weight, temperature capability etc. of all the equipments, systems/sub-systems offered for retroftment
(viii) Power flow diagram of the retrofitted system
(ix) Parasitic load of the auxiliaries used in the system

19.2 Following documents shall be submitted by the successful bidder, after issue of Letter of Acceptance at various stages of project to consignee as per requirement-

(i) Technical documentation explaining complete system including characteristic curves, inverter/convertor output curves and efficiency, diagnostics, and protection circuits etc.
(ii) Dimensional drawings (2D/3D) of all the equipments/systems/sub-systems with interface details offered for retrofitment
(iii) Control circuit diagram/schematic for proposed system

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(iv) Proposed Notch-wise Tractive Efforts Vs Speed curve
(v) Isolation sequencing plan in case of hydrogen leakage shall be submitted as per para 8.0 of this specification.
(vi) Test plan for the proposed system as per para 18.0 of this specification.
(vii) Procedure for user settable parameter alteration, fault data downloading and analysis etc.
(viii) Simulation study for regenerative energy as per para 16.0 of this specification
(ix) List of special tools, jigs and fixtures needed for testing, commissioning, maintenance and troubleshooting.
(x) Maintenance, troubleshooting and operating manuals with detailed information for all the equipment offered including all circuit diagrams in soft and hard copies. Renewal parts manual in soft and hard copies to be submitted.
(xi) Disaster management plan including detection, prevention, rescue, restoration plan shall be provided by the successful bidder for clearing the block section safely and for safe disembarkation/rescue of passengers.
(xii) Virtual animation of operating, assembly, repair and maintenance with user interface in 3D animation shall also be submitted in exe file for effective training of end users.

Irrespective of the details brought out here, all information and documentation which are essential for operation and maintenance of the DEMU DPC with the equipment supplied shall be submitted on request of Indian Railways.

20.0 Warranty:

Successful bidder shall be responsible for ensuring satisfactory performance of the Fuel cell based hybrid power train alongwith on-ground hydrogen infrastructure, during the warranty period. The complete system with controls shall be warranted for satisfactory and trouble free operation. All aspects of workmanship and design shall be covered by this warranty. The supplier shall immediately provide arrangement of rectification of failures reported under warranty within 06 hours of reporting. All the consumables/special tools/technical expertise/man power required during warranty period for satisfactory functioning of the system shall be provided by the successful tenderer.

Warranty period of any equipment of the system may be extended as per mutual agreement between consignee and supplier, if the equipment has undergone major design modifications during the warranty period.

The warranty period shall be of minimum 24 months that shall be counted from the date of successful commissioning i.e. date of start of field trials (as per para 18.4) of retrofitted fuel cell based hybrid power train.

21.0 Comprehensive Annual Maintenance Contract (CAMC):

The bidder shall also submit the offer for Comprehensive Annual Maintenance Contract (CAMC) including onground hydrogen infrastructure of the system for 03 year.

The period of CAMC of the system will be start after completion of warranty period. The contract shall be comprehensive in nature wherein preventive as well as breakdown

maintenance for all the retrofitted equipment, shall be done including supply of spares, tools, consumables, technically experienced man power. Bidder will ensure that 'Fuel Cell based Hybrid Power Train' shall run without interruption and will also maintain inventory of spares for successful operation.

The bidder should submit the preventive maintenance schedule at the time of submitting the offer. The successful bidders shall ensure that downtime on account of all maintenance (preventive and breakdown) of the equipment does not exceed a period equivalent of 10% of total hours for the Fuel cell based DEMU covered in the contract. The down time accountal shall be carried out every month and the successful bidder shall ensure not less than 90% availability on all the retrofitted equipment account, failing which suitable, penalty shall be leviable. The supplier shall immediately provide arrangement of rectification of failures reported under CAMC within 06 hours of reporting.

Based upon the experience gained by the successful bidder in the first year of the contract, it should be possible to improve upon the above referred level of the availability and downtime. The bidder should indicate the same in his offer.

22.0 Disaster Management:

Disaster management plan including detection, prevention, rescue, restoration plan shall be provided by the successful bidder for clearing the block section safely and for safe disembarkation/rescue of passengers.

23.0 Training:

The successful tenderer shall provide the necessary training for 600 mandays at firms premises and at the IR facility on operation, maintenance, troubleshooting, crew training and handling of the retrofitted fuel cell based hybrid power train and onboad/onground hydrogen infrastructure system.

Out of 600 mandays training, 200 mandays training will be provided at firm's premises and supplier of major equipments viz Fuel cell, Battery, Energy Management System, Hydrogen infrastructure etc. and 400 mandays training will be provided at IR facility.

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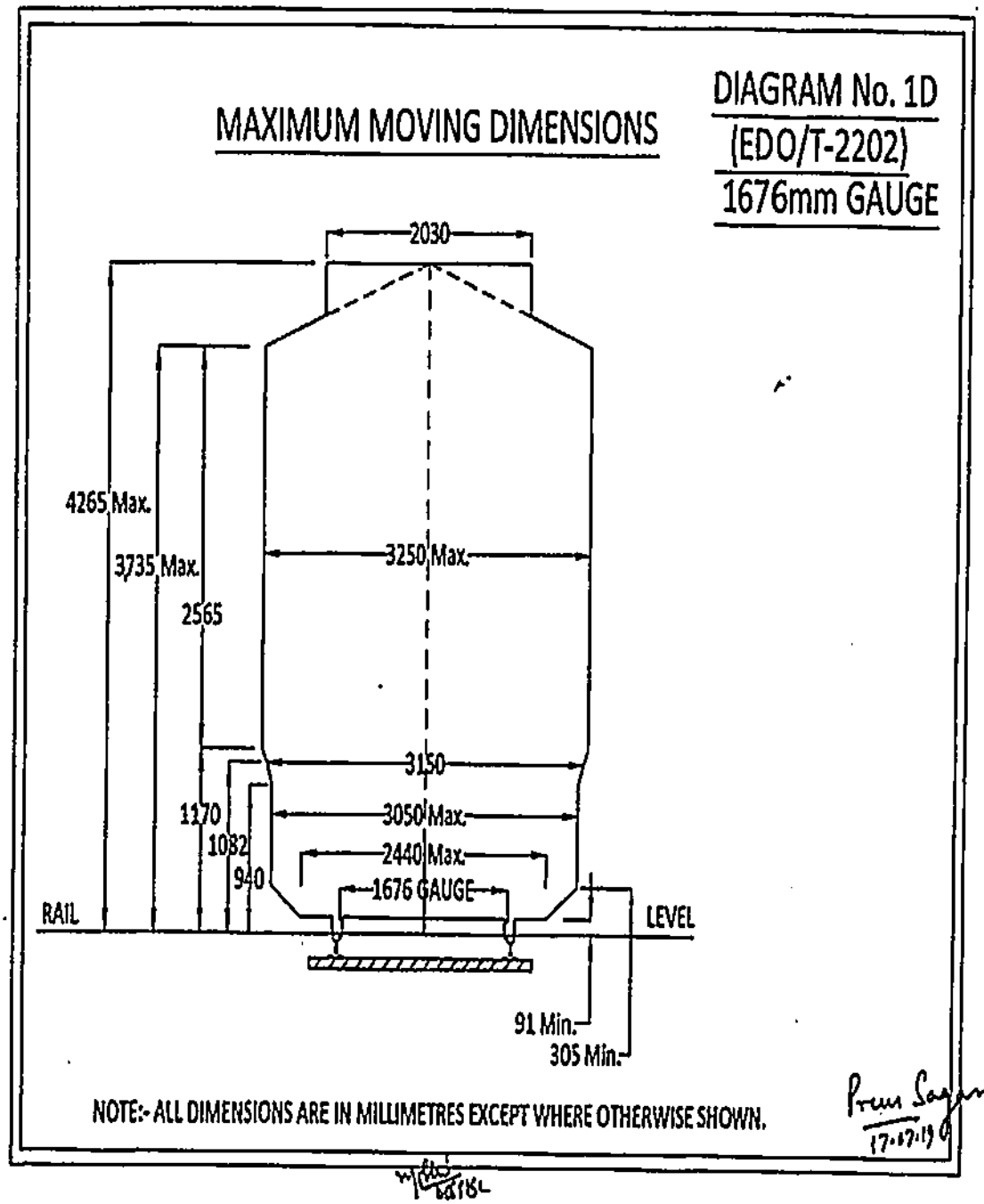
Annexure-I

Maximum Moving Dimensions



Annexure-II

Design Requirement for Hydrogen Fuel cell based hybrid power train system operating in Sonepat to Jind Section:

1.0 Section Details:

Sonepat-Jind section of Northern Railways has total distance of 89 Kms. The section has 12 no. halts. Altitude 300 meter approx. above mean sea level. For section details of sonepat-jind, drawing no.: DY.CE/C/CSB PLAN NO. IS-741/COMP/GHNA-SNP/2015.SH.2 may be referred. The firms are advised to acquaint themselves with the section and its topographical features.

2.0 Indicative rating of power train components based on actual drive cycle between Sonepat-Jindplus operating margins for variations in the driving cycle as a part of normal train operation can be taken as:

a. PEMFC of 800 KW Hydrogen fuel cell based power stacks preferably in the multiples of 100/150/200 KW).
b. Secondary energy source i.e battery bank of 330 to 380 KWH with power rating of400 KW.

Optimisation of power train components in terms of final rating to meet the actual drive cycle requirement (both peak and average) will have to done by bidder. Drive cycle of DEMU between Sonepat-Jind(up and down trip) is as under-

3.0 Indicative Driving cycle for Sonepat to Jind trip:

TIME (Scale: 0.1 step =15 seconds)	Notch	Power (HP)
0.1	2	466
0.2	2	466
0.3	0	143
0.4	0	143
0.5	1	211
0.6	2	466
0.7	2	466
0.8	3	699
0.9	3	699
1	3	699
1.1	3	699
1.2	3	699
1.3	4	951
1.4	5	1110
1.5	0	143
1.6	0	143

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1.7	3	699
1.8	5	1110
1.9	6	1326
2	6	1326
2.1	6	1326
2.2	6	1326
2.3	1	211
2.4	1	211
2.5	1	211
2.6	2	466
2.7	2	466
2.8	2	466
2.9	3	699
3	3	699
3.1	1	211
3.2	1	211
3.3	2	466
3.4	1	211
3.5	1	211
3.6	2	466
3.7	1	211
3.8	0	143
3.9	0	143
4	0	143
4.1	0	143
4.2	0	143
4.3	0	143
4.4	0	143
4.5	0	143
4.6	1	211
4.7	3	699
4.8	4	951
4.9	5	1110
5	6	1326
5.1	6	1326
5.2	6	1326
5.3	1	211
5.4	1	211
5.5	1	211
5.6	3	699
5.7	2	466
5.8	3	699
5.9	2	466
6	1	211
6.1	1	211

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6.2	1	211
6.3	2	466
6.4	2	466
6.5	2	466
6.6	2	466
6.7	2	466
6.8	2	466
6.9	1	211
7	2	466
7.1	1	211
7.2	2	466
7.3	0	143
7.4	0	143
7.5	0	143
7.6	0	143
7.7	0	143
7.8	0	143
7.9	0	143
8	0	143
8.1	1	211
8.2	2	466
8.3	0	143
8.4	0	143
8.5	0	143
8.6	0	143
8.7	0	143
8.8	0	143
8.9	0	143
9	0	143
9.1	0	143
9.2	0	143
9.3	2	466
9.4	3	699
9.5	3	699
9.6	0	143
9.7	0	143
9.8	0	143
9.9	2	466
10	4	951
10.1	4	951
10.2	5	1110
10.3	6	1326
10.4	6	1326
10.5	2	466
10.6	1	211

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10.7	1	211
10.8	2	466
10.9	1	211
11	1	211
11.1	0	143
11.2	0	143
11.3	1	211
11.4	2	466
11.5	2	466
11.6	2	466
11.7	3	699
11.8	4	951
11.9	0	143
12	0	143
12.1	0	143
12.2	0	143
12.3	0	143
12.4	0	143
12.5	0	143
12.6	1	211
12.7	2	466
12.8	4	951
12.9	5	1110
13	5	1110
13.1	6	1326
13.2	6	1326
13.3	6	1326
13.4	2	466
13.5	3	699
13.6	3	699
13.7	1	211
13.8	2	466
13.9	2	466
14	3	699
14.1	0	143
14.2	0	143
14.3	0	143
14.4	0	143
14.5	0	143
14.6	0	143
14.7	0	143
14.8	2	466
14.9	2	466
15	3	699
15.1	0	143

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15.2	0	143
15.3	0	143
15.4	0	143
15.5	0	143
15.6	0	143
15.7	0	143
15.8	0	143
15.9	0	143
16	3	699
16.1	4	951
16.2	5	1110
16.3	6	1326
16.4	6	1326
16.5	6	1326
16.6	1	211
16.7	2	466
16.8	3	699
16.9	3	699
17	2	466
17.1	2	466
17.2	3	699
17.3	0	143
17.4	0	143
17.5	0	143
17.6	0	143
17.7	0	143
17.8	0	143
17.9	0	143
18	0	143
18.1	0	143
18.2	0	143
18.3	0	143
18.4	0	143
18.5	0	143
18.6	0	143
18.7	0	143
18.8	0	143
18.9	0	143
19	0	143
19.1	0	143
19.2	2	466
19.3	2	466
19.4	3	699
19.5	0	143
19.6	0	143

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19.7	0	143
19.8	0	143
19.9	1	211
20	1	211
20.1	0	143
20.2	1	211
20.3	1	211
20.4	2	466
20.5	2	466
20.6	1	211
20.7	0	143
20.8	0	143
20.9	0	143
21	0	143
21.1	0	143
21.2	0	143
21.3	0	143
21.4	0	143
21.5	0	143
21.6	0	143
21.7	0	143
21.8	0	143
21.9	0	143
22	0	143
22.1	0	143
22.2	2	466
22.3	2	466
22.4	2	466
22.5	2	466
22.6	0	143
22.7	0	143
22.8	1	211
22.9	3	699
23	4	951
23.1	5	1110
23.2	6	1326
23.3	6	1326
23.4	6	1326
23.5	1	211
23.6	1	211
23.7	3	699
23.8	1	211
23.9	1	211
24	3	699
24.1	1	211

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24.2	1	211
24.3	1	211
24.4	1	211
24.5	1	211
24.6	0	143
24.7	0	143
24.8	0	143
24.9	0	143
25	0	143
25.1	0	143
25.2	0	143
25.3	2	466
25.4	4	951
25.5	5	1110
25.6	5	1110
25.7	6	1326
25.8	6	1326
25.9	1	211
26	0	143
26.1	0	143
26.2	1	211
26.3	2	466
26.4	1	211
26.5	1	211
26.6	1	211
26.7	3	699
26.8	3	699
26.9	1	211
27	0	143
27.1	0	143
27.2	0	143
27.3	0	143
27.4	0	143
27.5	0	143
27.6	0	143
27.7	0	143
27.8	0	143
27.9	2	466
28	3	699
28.1	3	699
28.2	4	951
28.3	6	1326
28.4	6	1326
28.5	6	1326
28.6	1	211

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28.7	1	211
28.8	1	211
28.9	1	211
29	2	466
29.1	2	466
29.2	0	143
29.3	0	143
29.4	0	143
29.5	0	143
29.6	0	143
29.7	0	143
29.8	2	466
29.9	3	699
30	5	1110
30.1	6	1326
30.2	6	1326
30.3	6	1326
30.4	6	1326
30.5	2	466
30.6	3	699
30.7	3	699
30.8	2	466
30.9	2	466
31	2	466
31.1	0	143
31.2	0	143
31.3	0	143
31.4	0	143
31.5	0	143
31.6	0	143
31.7	0	143
31.8	0	143
31.9	0	143
32	0	143
32.1	2	466
32.2	0	143
32.3	0	143
32.4	0	143
32.5	0	143
32.6	0	143
32.7	0	143
32.8	0	143
32.9	0	143
33	0	143
33.1	0	143

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33.2	0	143
33.3	0	143
33.4	0	143
33.5	0	143
33.6	0	143
33.7	0	143
33.8	0	143
33.9	0	143
34	0	143
34.1	0	143
34.2	0	143
34.3	0	143
34.4	0	143
34.5	0	143
34.6	0	143
34.7	0	143
34.8	0	143
34.9	0	143
35	0	143
35.1	0	143
35.2	0	143
35.3	0	143
35.4	0	143
35.5	0	143
35.6	0	143
35.7	0	143
35.8	0	143
35.9	0	143
36	0	143
36.1	0	143
36.2	0	143
36.3	0	143
36.4	0	143
36.5	0	143
36.6	0	143
36.7	0	143
36.8	0	143
36.9	0	143
37	0	143
37.1	0	143
37.2	0	143
37.3	0	143
37.4	0	143
37.5	0	143
37.6	0	143

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37.7	0	143
37.8	0	143
37.9	0	143
38	0	143
38.1	0	143
38.2	0	143
38.3	0	143
38.4	0	143
38.5	0	143
38.6	0	143
38.7	0	143
38.8	0	143
38.9	0	143
39	0	143
39.1	0	143
39.2	0	143
39.3	0	143
39.4	0	143
39.5	0	143
39.6	0	143
39.7	0	143
39.8	0	143
39.9	0	143
40	0	143
40.1	0	143
40.2	0	143
40.3	0	143
40.4	0	143
40.5	0	143
40.6	0	143
40.7	0	143
40.8	0	143
40.9	0	143
41	0	143
41.1	0	143
41.2	0	143
41.3	0	143
41.4	1	211
41.5	2	466
41.6	2	466
41.7	0	143
41.8	0	143
41.9	0	143
42	0	143
42.1	1	211

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42.2	0	143
42.3	0	143
42.4	3	699
42.5	4	951
42.6	4	951
42.7	1	211
42.8	1	211
42.9	0	143
43	0	143
43.1	1	211
43.2	1	211
43.3	1	211
43.4	1	211
43.5	1	211
43.6	2	466
43.7	2	466
43.8	2	466
43.9	0	143
44	0	143
44.1	0	143
44.2	0	143
44.3	0	143
44.4	0	143
44.5	0	143
44.6	1	211
44.7	2	466
44.8	2	466
44.9	2	466
45	1	211
45.1	2	466
45.2	1	211
45.3	0	143
45.4	0	143
45.5	0	143
45.6	0	143
45.7	0	143
45.8	0	143
45.9	0	143
46	0	143
46.1	0	143
46.2	0	143
46.3	0	143
46.4	0	143
46.5	0	143
46.6	0	143

46.7	0	143
46.8	0	143
46.9	0	143
47	0	143
47.1	2	466
47.2	4	951
47.3	4	951
47.4	4	951
47.5	1	211
47.6	1	211
47.7	1	211
47.8	1	211
47.9	0	143
48	0	143
48.1	0	143
48.2	0	143
48.3	0	143
48.4	0	143
48.5	1	211
48.6	2	466
48.7	0	143
48.8	0	143
48.9	0	143
49	1	211
49.1	3	699
49.2	1	211
49.3	1	211
49.4	1	211
49.5	2	466
49.6	2	466
49.7	2	466
49.8	1	211
49.9	0	143
50	0	143
50.1	0	143
50.2	0	143
50.3	0	143
50.4	2	466
50.5	3	699
50.6	0	143
50.7	0	143
50.8	0	143
50.9	0	143
51	0	143
51.1	0	143

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51.2	0	143
51.3	0	143
51.4	0	143
51.5	0	143
51.6	2	466
51.7	2	466
51.8	1	211
51.9	1	211
52	2	466
52.1	2	466
52.2	1	211
52.3	0	143
52.4	0	143
52.5	1	211
52.6	2	466
52.7	2	466
52.8	4	951
52.9	5	1110
53	3	699
53.1	0	143
53.2	0	143
53.3	0	143
53.4	0	143
53.5	0	143
53.6	2	466
53.7	3	699
53.8	3	699
53.9	0	143
54	0	143
54.1	0	143
54.2	0	143
54.3	0	143
54.4	0	143
54.5	0	143
54.6	0	143
54.7	0	143
54.8	0	143
54.9	0	143
55	1	211
55.1	1	211
55.2	0	143
55.3	0	143
55.4	0	143
55.5	0	143
55.6	0	143

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55.7	0	143
55.8	0	143
55.9	0	143
56	0	143
56.1	0	143
56.2	0	143
56.3	0	143
56.4	0	143
56.5	0	143
56.6	0	143
56.7	0	143
56.8	0	143
56.9	0	143
57	0	143
57.1	0	143
57.2	0	143
57.3	0	143
57.4	0	143
57.5	0	143
57.6	0	143
57.7	0	143
57.8	0	143
57.9	0	143
58	0	143
58.1	0	143
58.2	0	143
58.3	0	143
58.4	0	143
58.5	0	143
58.6	0	143
58.7	0	143
58.8	0	143
58.9	0	143
59	0	143
59.1	0	143
59.2	0	143
59.3	0	143
59.4	0	143
59.5	0	143
59.6	0	143
59.7	0	143
59.8	0	143
59.9	0	143
60	0	143
60.1	0	143

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60.2	0	143
60.3	0	143
60.4	0	143
60.5	0	143
60.6	0	143
60.7	0	143
60.8	0	143
60.9	0	143
61	0	143
61.1	0	143
61.2	0	143
61.3	0	143
61.4	0	143
61.5	0	143
61.6	0	143
61.7	0	143
61.8	0	143
61.9	0	143
62	0	143
62.1	0	143
62.2	0	143
62.3	0	143
62.4	0	143
62.5	0	143
62.6	0	143
62.7	0	143
62.8	0	143
62.9	0	143
63	0	143
63.1	0	143
63.2	0	143
63.3	0	143
63.4	0	143
63.5	0	143
63.6	0	143
63.7	0	143
63.8	0	143
63.9	1	211
64	2	466
64.1	0	143
64.2	0	143
64.3	0	143
64.4	0	143
64.5	1	211
64.6	1	211

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64.7	0	143
64.8	0	143
64.9	0	143
65	4	951
65.1	5	1110
65.2	6	1326
65.3	6	1326
65.4	1	211
65.5	1	211
65.6	1	211
65.7	1	211
65.8	2	466
65.9	2	466
66	1	211
66.1	1	211
66.2	1	211
66.3	0	143
66.4	0	143
66.5	0	143
66.6	0	143
66.7	0	143
66.8	0	143
66.9	0	143
67	0	143
67.1	0	143
67.2	0	143
67.3	0	143
67.4	0	143
67.5	0	143
67.6	0	143
67.7	0	143
67.8	0	143
67.9	0	143
68	0	143
68.1	0	143
68.2	0	143
68.3	0	143
68.4	0	143
68.5	0	143
68.6	0	143
68.7	0	143
68.8	0	143
68.9	0	143
69	0	143
69.1	0	143

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69.2	0	143
69.3	0	143
69.4	2	466
69.5	3	699
69.6	3	699
69.7	3	699
69.8	0	143
69.9	0	143
70	0	143
70.1	0	143
70.2	1	211
70.3	0	143
70.4	0	143
70.5	2	466
70.6	1	211
70.7	1	211
70.8	0	143
70.9	0	143
71	0	143
71.1	0	143
71.2	0	143
71.3	2	466
71.4	3	699
71.5	0	143
71.6	0	143
71.7	0	143
71.8	1	211
71.9	0	143
72	0	143
72.1	0	143
72.2	4	951
72.3	6	1326
72.4	6	1326
72.5	6	1326
72.6	2	466
72.7	1	211
72.8	0	143
72.9	0	143
73	0	143
73.1	0	143
73.2	0	143
73.3	0	143
73.4	0	143
73.5	0	143
73.6	0	143

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73.7	0	143
73.8	0	143
73.9	1	211
74	1	211
74.1	0	143
74.2	0	143
74.3	0	143
74.4	0	143
74.5	0	143

Driving cycle for Jind To Sonepat trip:

Time Scale 0.1 step=15 Seconds	Notch	Power (HP)
0.1	1	211
0.2	1	211
0.3	1	211
0.4	1	211
0.5	1	211
0.6	2	466
0.7	2	466
0.8	2	466
0.9	0	143
1	0	143
1.1	1	211
1.2	1	211
1.3	0	143
1.4	0	143
1.5	4	951
1.6	6	1326
1.7	6	1326
1.8	6	1326
1.9	1	211
2	0	143
2.1	0	143
2.2	0	143
2.3	3	699
2.4	3	699
2.5	0	143
2.6	0	143
2.7	0	143
2.8	0	143
2.9	0	143
3	1	211

3.1	1	211
3.2	0	143
3.3	0	143
3.4	0	143
3.5	0	143
3.6	0	143
3.7	0	143
3.8	2	466
3.9	2	466
4	0	143
4.1	0	143
4.2	1	211
4.3	1	211
4.4	0	143
4.5	0	143
4.6	0	143
4.7	1	211
4.8	4	951
4.9	6	1326
5	6	1326
5.1	6	1326
5.2	1	211
5.3	1	211
5.4	2	466
5.5	2	466
5.6	2	466
5.7	0	143
5.8	0	143
5.9	2	466
6	2	466
6.1	2	466
6.2	0	143
6.3	0	143
6.4	0	143
6.5	0	143
6.6	0	143
6.7	0	143
6.8	1	211
6.9	1	211
7	0	143
7.1	0	143
7.2	0	143
7.3	0	143
7.4	0	143
7.5	0	143

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7.6	0	143
7.7	0	143
7.8	0	143
7.9	0	143
8	1	211
8.1	2	466
8.2	2	466
8.3	2	466
8.4	0	143
8.5	0	143
8.6	0	143
8.7	1	211
8.8	1	211
8.9	0	143
9	1	211
9.1	1	211
9.2	1	211
9.3	0	143
9.4	1	211
9.5	4	951
9.6	5	1110
9.7	5	1110
9.8	5	1110
9.9	5	1110
10	0	143
10.1	0	143
10.2	0	143
10.3	0	143
10.4	0	143
10.5	2	466
10.6	2	466
10.7	1	211
10.8	0	143
10.9	0	143
11	0	143
11.1	0	143
11.2	0	143
11.3	0	143
11.4	0	143
11.5	0	143
11.6	0	143
11.7	2	466
11.8	3	699
11.9	3	699
12	2	466

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12.1	0	143
12.2	0	143
12.3	2	466
12.4	2	466
12.5	0	143
12.6	0	143
12.7	0	143
12.8	1	143
12.9	1	143
13	2	466
13.1	0	143
13.2	0	143
13.3	0	143
13.4	0	143
13.5	0	143
13.6	0	143
13.7	0	143
13.8	0	143
13.9	0	143
14	1	211
14.1	1	211
14.2	0	143
14.3	0	143
14.4	0	143
14.5	4	951
14.6	2	466
14.7	0	143
14.8	0	143
14.9	0	143
15	0	143
15.1	0	143
15.2	0	143
15.3	0	143
15.4	0	143
15.5	0	143
15.6	0	143
15.7	0	143
15.8	0	143
15.9	0	143
16	3	699
16.1	4	951
16.2	4	951
16.3	2	466
16.4	1	211
16.5	0	143

20/11/2021

16.6	0	143
16.7	0	143
16.8	2	466
16.9	2	466
17	1	211
17.1	1	211
17.2	1	211
17.3	1	211
17.4	1	211
17.5	1	211
17.6	1	211
17.7	0	143
17.8	0	143
17.9	0	143
18	0	143
18.1	0	143
18.2	0	143
18.3	1	211
18.4	2	466
18.5	2	466
18.6	2	466
18.7	1	211
18.8	1	211
18.9	0	143
19	0	143
19.1	0	143
19.2	0	143
19.3	0	143
19.4	0	143
19.5	0	143
19.6	2	466
19.7	2	466
19.8	0	143
19.9	0	143
20	0	143
20.1	0	143
20.2	1	211
20.3	1	211
20.4	0	143
20.5	0	143
20.6	0	143
20.7	0	143
20.8	0	143
20.9	0	143
21	0	143

26/11/2021

21.1	0	143
21.2	0	143
21.3	0	143
21.4	2	466
21.5	2	466
21.6	3	699
21.7	0	143
21.8	0	143
21.9	0	143
22	0	143
22.1	2	466
22.2	4	951
22.3	4	951
22.4	4	951
22.5	6	1326
22.6	6	1326
22.7	6	1326
22.8	0	143
22.9	0	143
23	0	143
23.1	0	143
23.2	0	143
23.3	0	143
23.4	0	143
23.5	0	143
23.6	0	143
23.7	0	143
23.8	0	143
23.9	0	143
24	0	143
24.1	0	143
24.2	2	466
24.3	3	699
24.4	6	1326
24.5	6	1326
24.6	6	1326
24.7	6	1326
24.8	6	1326
24.9	0	143
25	0	143
25.1	0	143
25.2	0	143
25.3	0	143
25.4	0	143
25.5	0	143

20/11/2021

25.6	0	143
25.7	0	143
25.8	0	143
25.9	2	466
26	3	699
26.1	6	1326
26.2	6	1326
26.3	6	1326
26.4	6	1326
26.5	6	1326
26.6	3	699
26.7	1	211
26.8	1	211
26.9	2	466
27	0	143
27.1	0	143
27.2	0	143
27.3	0	143
27.4	4	951
27.5	4	951
27.6	2	466
27.7	0	143
27.8	0	143
27.9	0	143
28	0	143
28.1	0	143
28.2	0	143
28.3	2	466
28.4	4	951
28.5	6	1326
28.6	6	1326
28.7	6	1326
28.8	6	1326
28.9	0	143
29	0	143
29.1	0	143
29.2	5	1110
29.3	5	1110
29.4	0	143
29.5	0	143
29.6	0	143
29.7	0	143
29.8	0	143
29.9	0	143
30	0	143

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30.1	0	143
30.2	0	143
30.3	0	143
30.4	0	143
30.5	0	143
30.6	1	211
30.7	2	466
30.8	3	699
30.9	1	211
31	0	143
31.1	0	143
31.2	0	143
31.3	0	143
31.4	0	143
31.5	0	143
31.6	0	143
31.7	0	143
31.8	0	143
31.9	0	143
32	1	211
32.1	1	211
32.2	0	143
32.3	0	143
32.4	0	143
32.5	0	143
32.6	0	143
32.7	0	143
32.8	0	143
32.9	0	143
33	0	143
33.1	1	211
33.2	2	466
33.3	3	699
33.4	3	699
33.5	0	143
33.6	0	143
33.7	0	143
33.8	0	143
33.9	4	951
34	6	1326
34.1	6	1326
34.2	6	1326
34.3	6	1326
34.4	6	1326
34.5	0	143

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34.6	0	143
34.7	0	143
34.8	0	143
34.9	0	143
35	4	951
35.1	4	951
35.2	4	951
35.3	4	951
35.4	1	211
35.5	0	143
35.6	0	143
35.7	0	143
35.8	0	143
35.9	0	143
36	0	143
36.1	0	143
36.2	0	143
36.3	0	143
36.4	0	143
36.5	0	143
36.6	4	951
36.7	5	1110
36.8	6	1326
36.9	6	1326
37	6	1326
37.1	6	1326
37.2	1	211
37.3	1	211
37.4	2	466
37.5	3	699
37.6	2	466
37.7	2	466
37.8	1	211
37.9	3	699
38	3	699
38.1	3	699
38.2	3	699
38.3	1	211
38.4	0	143
38.5	0	143
38.6	0	143
38.7	4	951
38.8	1	211
38.9	0	143
39	0	143

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39.1	0	143
39.2	0	143
39.3	0	143
39.4	0	143
39.5	0	143
39.6	0	143
39.7	2	466
39.8	4	951
39.9	6	1326
40	6	1326
40.1	6	1326
40.2	6	1326
40.3	5	1110
40.4	1	211
40.5	1	211
40.6	1	211
40.7	1	211
40.8	1	211
40.9	1	211
41	1	211
41.1	1	211
41.2	2	466
41.3	3	699
41.4	2	466
41.5	0	143
41.6	0	143
41.7	0	143
41.8	0	143
41.9	0	143
42	0	143
42.1	0	143
42.2	0	143
42.3	0	143
42.4	1	211
42.5	1	211
42.6	0	143
42.7	0	143
42.8	0	143
42.9	0	143
43	0	143
43.1	0	143
43.2	0	143
43.3	1	211
43.4	2	466
43.5	2	466

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43.6	2	466
43.7	2	466
43.8	0	143
43.9	0	143
44	0	143
44.1	2	466
44.2	4	951
44.3	5	1110
44.4	5	1110
44.5	5	1110
44.6	5	1110
44.7	5	1110
44.8	2	466
44.9	1	211
45	3	699
45.1	3	699
45.2	2	466
45.3	2	466
45.4	0	143
45.5	0	143
45.6	0	143
45.7	0	143
45.8	4	951
45.9	1	211
46	1	211
46.1	1	211
46.2	1	211
46.3	2	466
46.4	2	466
46.5	2	466
46.6	0	143
46.7	0	143
46.8	0	143
46.9	0	143
47	0	143
47.1	0	143
47.2	0	143
47.3	0	143
47.4	0	143
47.5	0	143
47.6	3	699
47.7	4	951
47.8	4	951
47.9	5	1110
48	6	1326

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48.1	6	1326
48.2	6	1326
48.3	6	1326
48.4	0	143
48.5	0	143
48.6	0	143
48.7	5	1110
48.8	5	1110
48.9	5	1110
49	0	143
49.1	0	143
49.2	0	143
49.3	0	143
49.4	0	143
49.5	0	143
49.6	0	143
49.7	0	143
49.8	0	143
49.9	0	143
50	0	143
50.1	0	143
50.2	0	143
50.3	0	143
50.4	0	143
50.5	0	143
50.6	0	143
50.7	0	143
50.8	0	143
50.9	0	143
51	0	143
51.1	0	143
51.2	0	143
51.3	1	211
51.4	0	143
51.5	0	143
51.6	0	143
51.7	1	211
51.8	0	143
51.9	0	143
52	0	143
52.1	0	143
52.2	0	143

- **The Sonepat-Jind section may be treated as level terrain for all calculations.**

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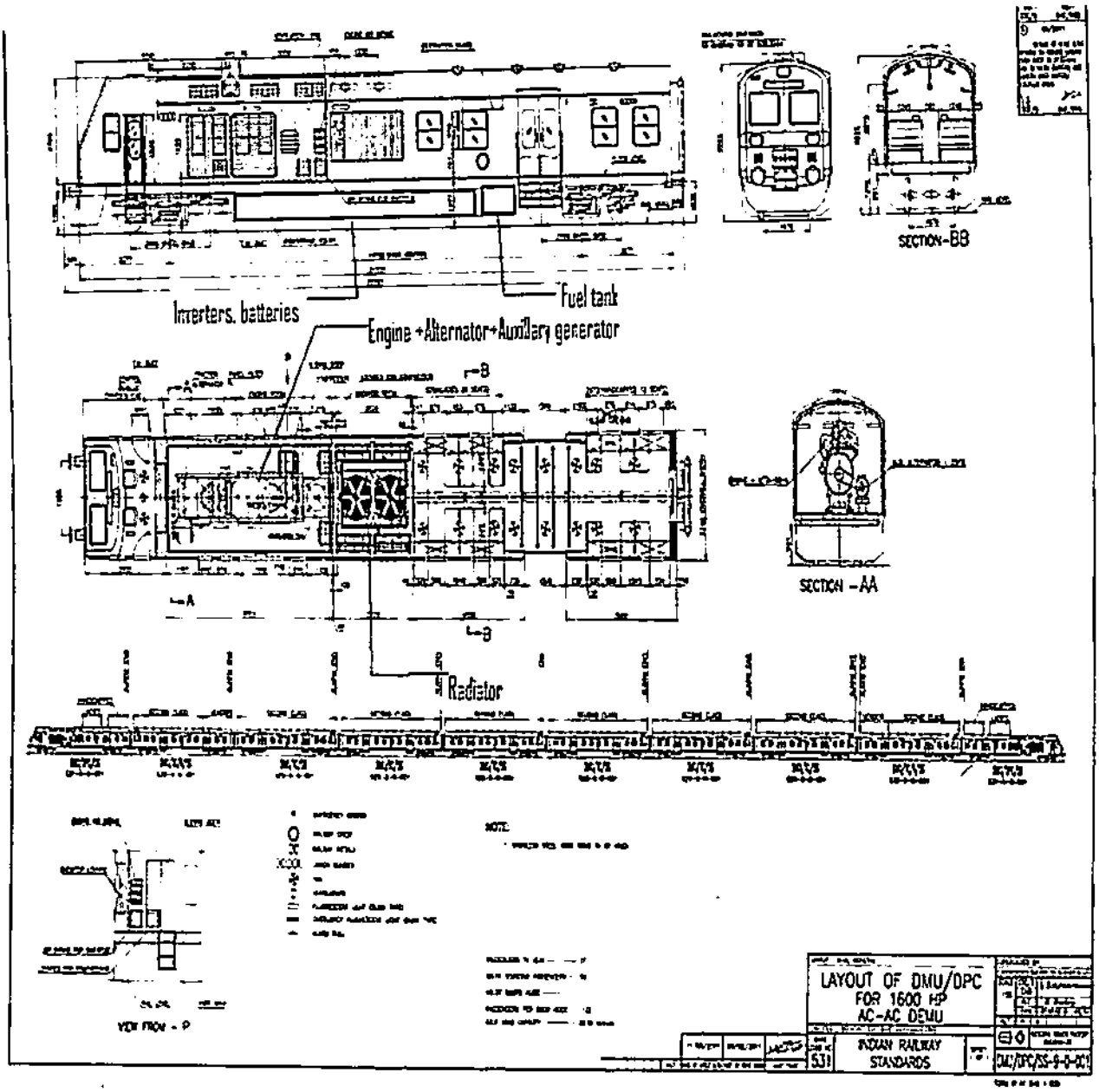
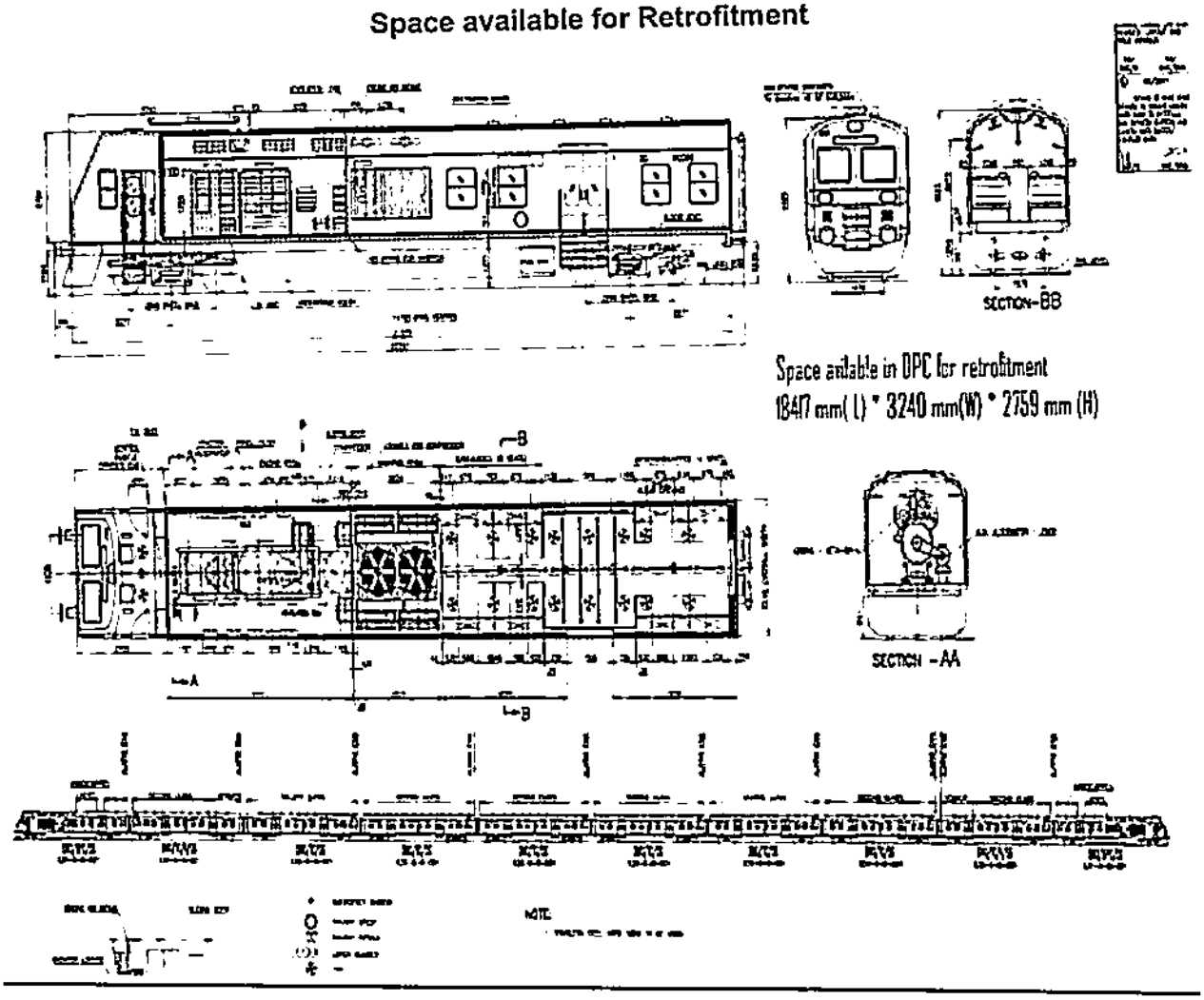
Annexure-III

Equipments to be removed from DEMU



Annexure-IV

Space available for Retrofitment



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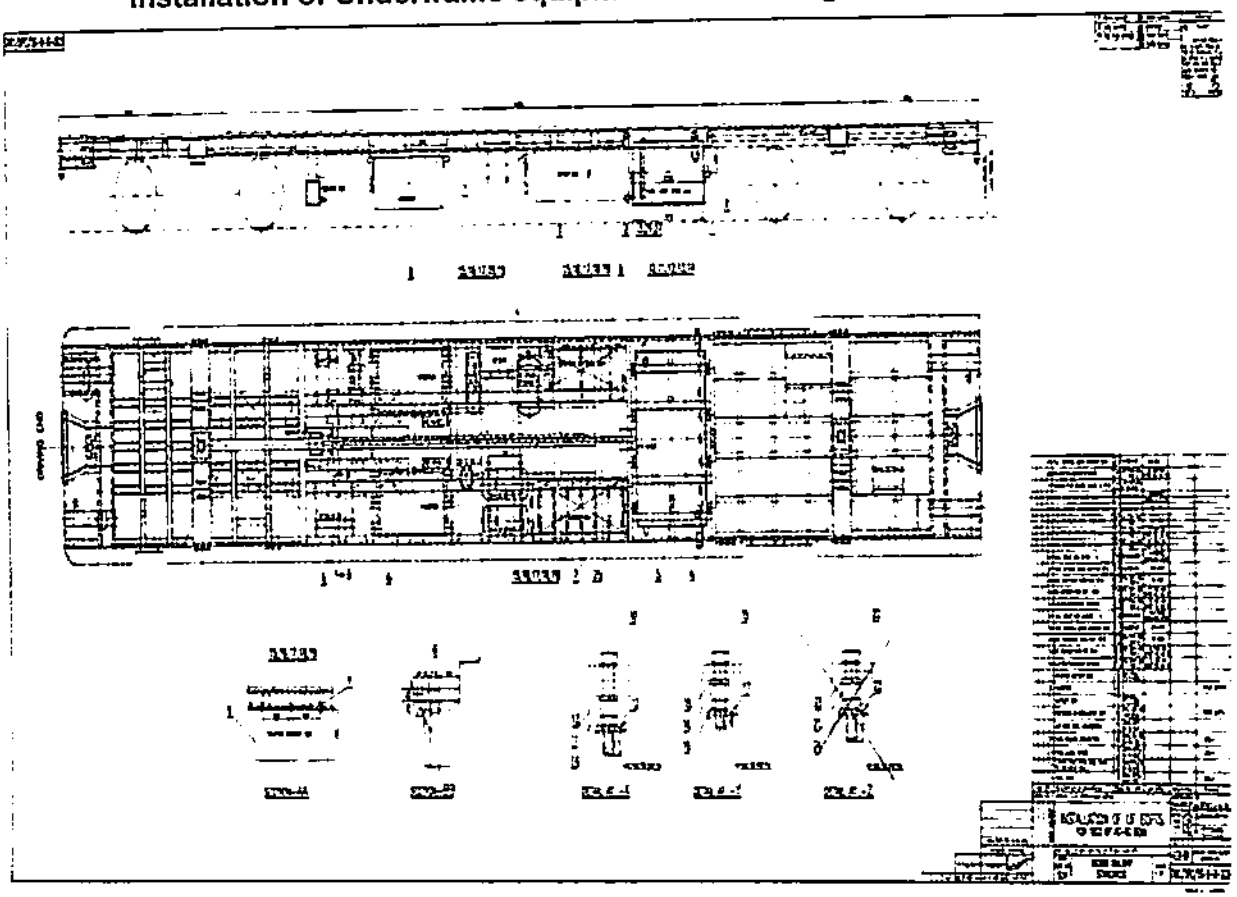
Annexure-V

Installation of Underframe equipments in existing 1600 HP DEMU



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Annexure-VI

Parameters to be monitored under Remote Diagnostic System-

Parameters needs to be recorded for efficient working of the system which includes fuel cell and its balance of plant, propulsion system, battery health, regenerative braking system, hydrogen storage, electrical control system etc. is mentioned below-

System	Parameters (indicative list)
Fuel Cell and its balance of plant:	Output Voltage, Current, Power output, efficiency, temperature of fuel cell, hydrogen supply pressure to fuel cell, air delivery pressure to fuel cell etc.
Electrical Control system	Input/output voltage and current at various stages, temperature etc.
Battery Health	State of Charge (SOC), Depth of Discharge (DOD) Alarms, temperature of battery bank, Voltage and current, energy level etc.
Hydrogen Storage	Pressure and Temperature of the cylinders, supply line, refilling rate of H2, leakage alarms, H2 available in storage tanks etc.

In addition to above, additional parameters for braking system effectiveness, regenerative braking, electrical control system, propulsion system etc. that consignee needs to monitor may be adopted and mentioned by the consignee in the table given below.

System	Parameters

The above list is not exhaustive, any other parameter which is considered necessary shall be monitored for efficient functioning of the retrofitted hydrogen fuel cell based power train.

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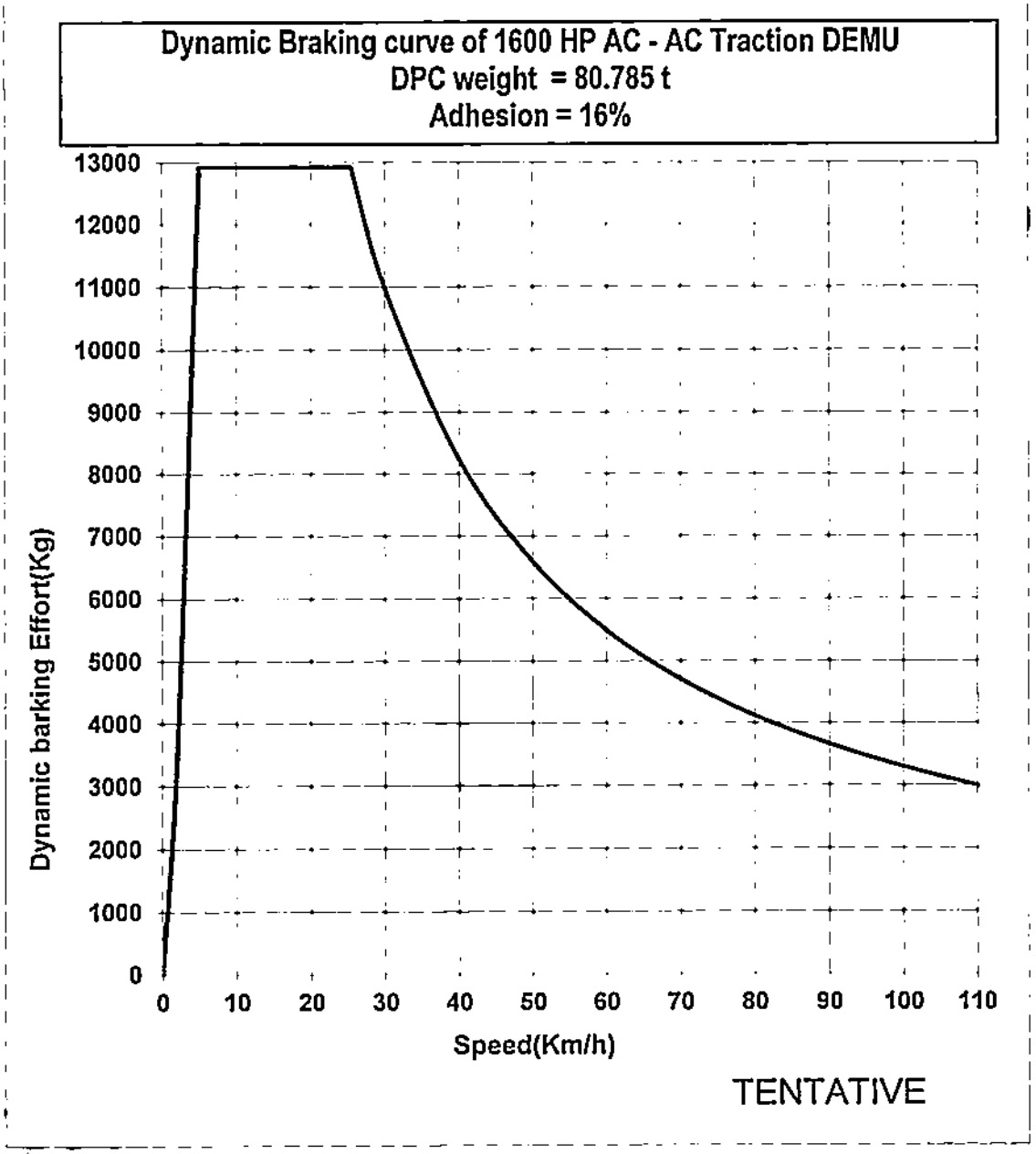
Annexure-VII



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SSE/mech.

28/11/2021
ADEN