सत्यमेव जयते

Government of India
Ministry of Railways

Functional Requirement Specifications

For

Hydrogen Fuel cell based Narrow Gauge Locomotive for Kalka- Shimla

Specification No. R2/347/Fuel Cell-2

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Research Directorate
Research Design & Standards Organization
Manak Nagar, Lucknow - 226011

Contents

Abbreviations

- 'IR' means Indian Railways.
- 'RDSO' means Research Designs and Standards Organization, Ministry of Railways, Manak Nagar, Lucknow-226 011.
- 'NG' means 762 mm gauge, referred to as Narrow Gauge.
- 'IEC' means International Electro-technical Commission.
- 'IS' means Indian Standard.
- 'AAR' means Association of American Rail-roads.
- 'UIC' means Union International Des Chemis defer (International Union of Railways)
- 'IRS' means Indian Railway Standard.

Throughout this specification the words:

- Horse Power (HP) shall be taken as metric horse Power.
- Tonnes (T) shall be taken as metric tonne
- BOP- Balance of Plant
- EMS- Energy management Strategy
- SOC- State of charge
- DOD- Depth of Discharge
- PEMFC- Proton Exchange membrane Fuel cell
- MMD- Maximum Moving Dimension

1.0 Purpose

To develop fuel cell/battery based hybrid power train along with associated control and suitably designed Energy Management Strategy (EMS) and storage module for retrofitment on 700 HP Narrow Gauge ZDM3 Diesel- Hydraulic Locomotives running on Kalka- Shimla section for drive cycle enclosed as Annexure-III.

2.0 Background

The hydrogen fuel cell based rail propulsion technologies powered by PEMFC (proton exchange membrane based Fuel Cell) alongwith 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 700 HP Narrow Gauge ZDM3 Diesel-Hydraulic Locomotive running on Kalka-Shimla section into hybrid fuel cell and battery based Locomotive.

For equipment layout of ZDM3 Diesel Hydraulic Locomotive running in narrow gauge Kalka- Shimla section, RDSO Drawing No.:SK.DP-3944 may be referred. Technical details of ZDM3 Loco plying in Kalka Shimla section are enclosed as Annexure-II for reference.

3.0 Design requirements

Hydrogen fuel cell based power stacks (Primary energy source PEMFC) alongwith the complete support and auxiliary systems like energy storage module (Secondary energy source i.e. Battery Bank), 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 for the complete driving cycle, including up and down trips, based on a suitably designed EMS (Energy Management Strategy). The complete system will have to be retrofitted on existing Narrow Gauge ZDM3 Diesel-Hydraulic Locomotive.

The total energy requirement for up and down trips, based on actual driving cycle, is 1556 kwh and 1170 kwh respectively. Power train, consisting of primary energy source as PEMFC and secondary energy source i.e battery bank, should be able to meet the peak power requirement as per the enclosed driving cycle. The power train should be so designed that it has minimal weight and space implications onboard of the loco and does not exceed the structural strength limits of the locomotive underframe, bogies and super structure. Optimization should include all accessories and balance of plant (BOP) in compliance with axle load limits and other structural strength requirements. The Energy management strategy (EMS) should be so designed that the State of Charge(SOC) of the battery largerly remains same from start of cycle to end of cycle. The Depth of Discharge(DOD) of battery should be preferably limited to 30%. An indicative break-up of hybrid power train components to meet the above requirement is (a) 450 kw PEMFC (b) suitably rated battery bank to meet the peak requirement as per the enclosed driving cycle.

The Hydrogen Fuel Cell Retrofitment kit along with the Balance of Plant and Energy Storage/Hydrogen Storage modules will replace the existing power-train items onboard Narrow Gauge ZDM3 Diesel-Hydraulic Locomotives including drive components like Engine with foundation plate, Engine oil, air intake connection, exhaust connection, smoke box,

exhauster and compressor, fuel tank, fuel HSD, upper ballast in buffer end, ballast in radiator end, Lower ballast in buffer end and battery box (03 batteries) which weighs approximately to 9.4 tons.

The Retro fitment scheme targets retention/ replacement /addition of following components/ sub-assemblies:

a) Existing hydraulic Transmission system shall be retained. Drive to the transmission will be coupled to a 3 phase VVVF controlled AC motor of suitable power rating and speed to supply the requisite torque levels at the desired RPMs.

b) A motor driven expressor/compressor/exhauster will be used for braking requirements.

c) The fuel cell control system will be interfaced with the locomotive control console in such a way that the drivers HMI/MMI/Control desk interfaces remains unchanged.

d) Suitable heat exchanger/radiator should be designed to cool the hydraulic/transmission oil of the hydraulic transmission of the locomotive.

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

a. Existing ZDM3 Diesel-Hydraulic Locomotive Bogies shall not be altered/changed.
b. Locomotive underframe to bogie interface shall not be altered/changed.
c. As per the locomotive GA/architecture, the space available on platform for retrofitment will be around 6.99(L) x 2.24(W) x 2.085(H) m. In addition, the space released by fuel tank under the platform can also be utilized for mounting of equipments subject to condition that the axle load limits and the MMD stipulations are not exceeded.
d. Axle Load of ZDM3 Diesel-Hydraulic Locomotive with the retrofitted equipments shall not exceed 9.25 Tons.
e. The layout shall be designed so as to not disturb the existing Centre of Gravity of ZDM3 Diesel-Hydraulic Locomotive.
f. Mounting of equipment/sub-assemblies shall not create infringement with IRSOD for Narrow gauge latest amendment.
g. Peak Power rating of the Fuel cell based ZDM3 Diesel-Hydraulic Locomotive shall be 700 HP/522 KW. The typical driving cycle of 700 HP ZDM3 Diesel-Hydraulic Locomotive presently operating in Kalka- Shimla Section of Northern Railway is enclosed as Annexure-III.
h. The Energy Management Strategy (EMS) shall be so designed that with the power-train rating mentioned under para 3 above and the train operation requirements as per the typical driving cycle enclosed as Annexure-III, the State of Charge (SOC) of the battery bank at the start of the driving cycle and the end of the driving cycle remains the same.
i. Suitable Hydrogen fuel storage system will be a part of the retro-fitment kit. Hydrogen storage module shall be such that it will cater to one trip of Up and Down direction operation of approximately 220 Kms in total. Hydrogen shall be preferably stored on top. Requirement of Hydrogen fuel storage on-board shall be calculated based on driving cycle/duty cycle and the total distance to be traveled.

j. 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.

k. Air brake/Vacuum 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.

l. Inbuilt 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 stays operational during train service.

4.0 Other functional requirements

i. Technical design features of all the major equipment such as fuel cell stacks, hydrogen storage system, battery, converter etc. and controls shall be governed by the relevant IEC/International/IR/RDSO standards.

ii. The fuel cell design and associated equipments forming the part of BOP and having interface with Hydrogen storage modules and heat exchangers shall be based on a working design / design under trial or under pilot implementation anywhere in the world on a Metro Rolling Stock, Trams, Rail Cars, Locomotives, Sub-urban transport systems etc. IR shall evaluate the various designs based upon cost of operation, commercial availability, maintainability, life cycle costing, dimensions/ footprint of the proposed equipment, use in similar applications etc. The efficiency of the system shall not be less than the internationally accepted industry standards and the emissions shall be minimal.

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

v. The fuel cell stack details provided as under are indicative and only for guidance.

PEMFC - Proton Exchange Membrane (PEM) Fuel Cells.

i. Very low maintenance cost.

ii. There shall be no emissions or discharge of any harmful substances such as lead etc.

iii. It shall produce clean DC power with a low thermal and acoustic signature. Existing hydraulic Transmission system shall be retained. Drive to the transmission will be coupled to a 3 phase VVVF controlled asynchronous motor of suitable power rating and speed to supply the requisite torque levels at the desired RPMs

iv. The system shall be compact with modular construction.

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

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

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

viii. 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 the safety of the passengers on-board.

ix. The hydrogen storage units shall be of adequate pressure rating 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.

x. The design of Fuel cell based Narrow Gauge ZDM3 Diesel- Hydraulic Locomotive should facilitate re-filling/unit replacement of empty Hydrogen tanks with filled Hydrogen tanks within 45 minutes using manual efforts. The design should have provision for refilling of the empty Hydrogen cylinder in in-situ conditions on- board using a suitably designed Hydrogen refilling system within a reasonable time not exceeding 45 minutes. The replacement of empty cylinders will continue till the time the hydrogen storage & refilling facility is set-up by Indian Railways at the nominated yards. Till the time way-side Hydrogen storage/filling facility is developed by IR, the design should facilitate manual replacement in in-situ condition in yards/platforms/depots of the empty Hydrogen cartridge/cylinders with filled cylinders carrying Hydrogen at 350 bar.

xi. Remote diagnostics (optional feature): Narrow Gauge ZDM3 Diesel- Hydraulic Locomotive shall be equipped with remote diagnostics wherein critical ZDM3 Diesel-Hydraulic Locomotive health monitoring of systems like Battery system, fuel cell stacks, hydrogen storage, DC voltage bus, cooling system, braking and other vital parameters of the Diesel- Hydraulic Locomotive controls should be available for identifying defective or failed components of the hybrid power train.

xii. Operating requirements:

Sharpest curve to be negotiated	Ruling gradient of the section is 1 in 33 and sharp curves of 48^0
700 HP Narrow Gauge ZDM3 Diesel-Hydraulic Locomotive weight Nominal Axle Load	Not exceeding 37 t Not exceeding 9.25 t
Maximum Operating Speed. Maximum permitted speed	35 kmph 25 kmph

5.0 Scope of work

The scope will cover Design, supply, retrofitment, testing & validation, prove out, field trials, of fuel cell & battery based power stack modules, hydrogen storage, power electronics/controls & associated equipments including necessary engineering & supervision work for retrofitment of Narrow Gauge ZDM3 Diesel- Hydraulic Locomotive. The interfacing of the Fuel Cell Stack Controller with HMI/MMI/Driver interface shall be a part of the Scope of work.

A. An indicative list of the equipment covered in scope of supply is as under :

a. Hydrogen storage tank(s)/Cylinder(s)
b. Piping and control, safety, sensing devices for hydrogen storage
c. Cables
d. Hydrogen Fuel cell stack modules
e. Air delivery, and Cooling Systems
f. Battery Module
g. Gauges & Fittings
h. Control console / HMI / MMI
i. Auxiliary power systems
j. Microprocessor based control system with instrumentation, actuators, motor controllers, and a programmable automation controller (PAC) including AC drive motor control, Converters/Inverters etc.
k. Remote diagnostic system
l. Any other accessory/sub system/sub assembly required for satisfactory functioning of system
m. Motor driven expressor and heat exchanger/radiator for cooling of hydraulic transmission oil

However, the list above is not exhaustive. Any other component / Assembly / Software/ Hardware etc., that is required for proper functioning of the retrofitted equipments, will have to be supplied as a part of scope of work.

6.0 Environmental conditions

Design factors such as weight, center of gravity, packaging and safety requirements etc. among other features shall have to be considered. Complete system after retrofitment shall have to be done considering the harsh operating conditions, especially shock loads during marshalling in yard/depots, this shall essentially require component mounting systems capable of absorbing high energy. Additionally, system design shall address Indian Railway regulations governing safety and such events as derailment, side impact from yard traffic, refueling and maintenance.

Fuel cell based Narrow Gauge ZDM3 Diesel- Hydraulic Locomotive shall be required to work continuously under following atmospheric conditions:

Maximum temperature (Atmospheric)	(i) 55 **º**C (under sun). (ii) 47 **º**C (in shade)
Humidity	90 % (Up to 100% during rainy season.)
Altitude	Max. 2100 meter above mean sea level
Reference site conditions	Ambient temp. -10^{0}C to 55 **º**C (Max)
Dust	May have to operate in extremely dusty environment.

All the equipment and their mounting arrangement shall satisfactorily withstand the vibrations and shocks as indicated below:

- The maximum allowable acceleration in longitudinal, lateral, and vertical directions for the fuel-cell hardware shall be 3g *('g' being acceleration due to gravity)*. This 3g maximum limit applies at or below the system natural frequency.

7.0 International / National standards

1. The fuel cell stack should conform to the relevant clauses of the standards listed below:

ISO 23273-1:2006 Fuel Cell road vehicles specification – Part-1: Vehicle functional safety

- 6.1.1 Fail safe design
- 6.1.2 First failure response
- 6.3 Connections (Electrical & Mechanical)

ISO 23273-2:2006 Fuel Cell road vehicles specification – Part-2: Protection against hydrogen hazards for vehicles fuelled with compressed hydrogen

- 5.2.1 General component requirements
- 5.2.3 Overpressure protection
- 5.2.4 Hydrogen shutoff system
- 5.4 Discharges

ISO 23273-322006 Fuel Cell road vehicles specification – Part-3: Protection of persons against electric shock

- 6.1 Electrical equipment marking
- 6.2 Identification of voltage class B wiring
- 8.2.3 Insulation resistance measurement of voltage class B electric power sources
- 8.2.5 Voltage withstand capability
- 8.3.2 Protection degrees for barriers/enclosures
  8.3.3 Continuity requirements for potential equalization.

• System Shall be designed to withstand vibrations as per IEC-60571

8.0 Hydrogen storage

Hydrogen fuel storage shall use readily available hardware and should comply to all safety regulations / certifications related with hydrogen safety measures. Modules shall be mounted as per approved layout, each consisting of adequate no. of carbon fiber/aluminum tanks.

Each 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 (above 109 °C), such as could be caused by a battery fire, the thermally activated 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 ZDM3 Diesel- Hydraulic

Locomotive to allow non-operators or refueling personnel to shut down the fuel system.

9.0 Battery System

The Lithium Ion 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.).

10.0 Driving Cycle

The Driving Cycle of ZDM3 Diesel- Hydraulic Locomotive presently operating in Kalka to Shimla section of Northern railway is enclosed as Annexure-III.

11.0 Fuel Cell based Power-Train Control System & its Integration with HMI/MMI/Driver Interface/Drivers' control desk

The existing HMI *(Driver Interface) shall remain unchanged. However, the PEMFC and Battery parameters shall be incorporated for display on the MMI/HMI display in the existing control console. The information to be displayed to the driver/assistant on the driver desk / control dashboard shall be decided mutually between IR and the Fuel Cell System designer.

12.0 Mounting and Isolation

Mounting of all fuel cell system modules to the ZDM3 Diesel- Hydraulic Locomotive is of critical importance because Diesel- Hydraulic Locomotive are marshaled in rail yards, which can lead to shock loads up to 10 Gs (11 ms saw tooth). 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 shall be used to validate all structural weldment designs.

13.0 Documentation

Following documents shall be submitted to IR for evaluation:

- Functional description of the complete system, including salient features and advantages of the offered system
- All performance curves, including the proposed notch-wise TE Vs Speed, fuel efficiency, efficiency and ventilation characteristics of the major equipment offered, parasitic load of the auxiliaries used in the system, basic design data like ratings, power circuit diagram and temperature capability, envelope and mounting drawings etc. shall be submitted with the offer.

a) Technical documentation explaining the complete system including characteristic curves and efficiency, diagnostics and protection circuits etc.
b) ZDM3 Diesel- Hydraulic Locomotive control circuit line diagram.

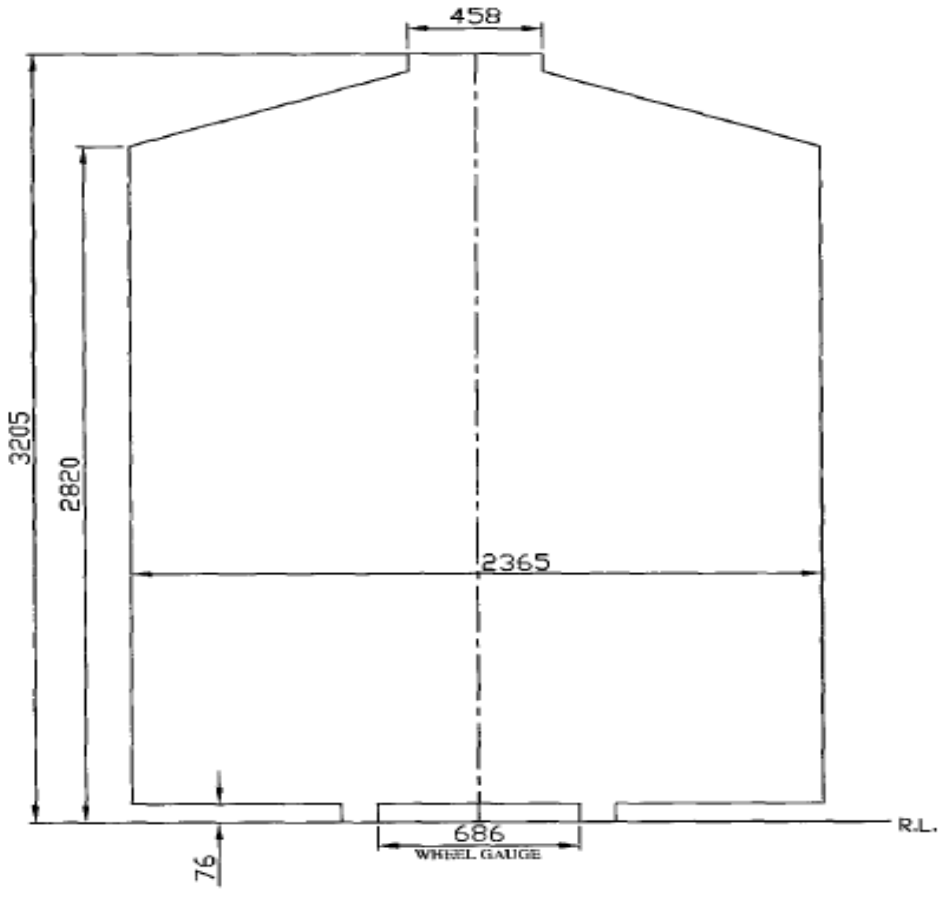
c) Lay out and mounting drawings of all the equipment offered
d) Layout and mounting drawings of each sub-system with interface details.
e) Cooling system details.
f) Procedure for user settable parameter alteration, fault data downloading and analysis etc.
g) Recommended list of spares for 3 years with price.
h) List of special tools, jigs and fixtures needed for testing, commissioning, maintenance and repair.
i) Maintenance, troubleshooting and operating manuals with detailed information for all the equipment offered in soft and hard copies. Renewal parts manual in soft and hard copies.

Irrespective of the details brought out here, all information and documentation which are essential for operation and maintenance of the ZDM3 Diesel- Hydraulic Locomotive with the equipment supplied shall be submitted on request of Indian Railways.

Annexure-I

INDIAN RAILWAYS
RDSO (MP)

MAXIMUM MOVING DIMENSIONS FOR 762mm NG DIESEL HYDRAULIC LOCO (FOR KALKA-SHIMLA SECTION ONLY)



D									SCALE: 1:20	REF:	
C										DRG. NO. SK.DP- 3914	
APPD		ALL DIMENSIONS ARE IN mm.									
Dt.	2.9.09	ALT.	NO. OF PLACES	REF. NO.	DESCRIPTION	ALT. SHTS. NO.	SIGN.	DATE	FIRST ISSUED	SUPERSEDES	SUPERSEDED BY

Annexure-II

Technical details of ZDM3 locos (for KLK-Shimla)

S.No.	Particulars	ZDM_3 (mfd by Parel)
1.	Gauge (mm)	762
2.	Sharpest curve	48°
3	Max. gradient	1 in 33
4.	Wheel Arrgt.	B'-B'
5.	Wheel dia (mm)	700
6.	Wheel base(mm)	1590
7.	Loco length (mm)	10300
8.	Loco width (mm)	2240
9.	Loco height (mm)	3180
10.	Wt. of loco (t)	37
11.	Adhesive weight (t)	37
12.	Axle load (t)	9.25
13.	Max. T.E (t)	11.1 t
14.	Max. Brake power (ref drg. No.12.08.14	30400 kg
15.	Max. Braking force	9.12 t (for whole loco) 9.12/4=2.28t per axle
16.	C.G from R.L.	Max. 740mm
17.	Fuel Capacity	1400 liters
18.	Max. Operating Speed(kmph)	35 km/h
19.	Max. permitted speed in KLK-SML	25 km/h
20.	Continuous speed km/h	8
21.	TE (t)	10.5 (Limited by adhe.) 10.6 (Special device)
22.	Sharpest curve negotiable	35 m Radius (50°)
23.	Engine	CIL make VTA-1710L
24.	Rated power of engine	(700hp) = 522 kW
25.	Idle speed(rpm)	600
26.	Rated speed of engine	2100
27.	Transmission	Voith L4r2U2
28.	Axle Drive:	KPC Make
29.	G. Ratio Primary: Secondary:	4.58:1 - 25 km/h 3.09:1
30.	Brake system	Vacuum & air brake
31.	Compressor	TRC 1000 B
32.	Exhauster	
33.	Cab	Dual cab at end of loco

Annexure-III

***Driving Cycle of ZDM3 Diesel- Hydraulic Locomotive in KALKA - SHIMLA section of Northern Railway**

Note - The master controller provided in the locomotive is stepless type. For mapping the driving cycle, the continuous stepless range has been converted into 8 discrete power set points covering the complete range.

Drive cycle for Kalka to Shimla Section :

Time(min)	Notch	Power(HP)
0	1	87.5
2	6	525
4	7	612.5
6	7	612.5
8	7	612.5
10	7	612.5
12	6	525
14	6	525
16	4	350
18	8	700
20	7	612.5
22	7	612.5
24	7	612.5
26	6	525
28	7	612.5
30	8	700
32	8	700
34	8	700
36	7	612.5
38	7	612.5
40	7	612.5
42	7	612.5
44	7	612.5
46	5	437.5
48	7	612.5
50	7	612.5
52	7	612.5
54	7	612.5
56	6	525
58	7	612.5

Time(min)	Notch	Power(HP)
60	7	612.5
62	7	612.5
64	7	612.5
66	7	612.5
68	4	350
70	7	612.5
72	7	612.5
74	7	612.5
76	1	87.5
78	7	612.5
80	7	612.5
82	7	612.5
84	7	612.5
86	6	525
88	6	525
90	7	612.5
92	1	87.5
94	0	0
96	0	0
98	0	0
100	3	262.5
102	7	612.5
104	7	612.5
106	6	525
108	6	525
110	6	525
112	5	437.5
114	6	525
116	0	0
118	3	262.5
120	1	87.5
122	1	87.5
124	4	350
126	3	262.5
128	0	0
130	0	0
132	0	0
134	0	0
136	0	0
138	1	87.5
140	5	437.5
142	4	350
144	4	350
146	6	525
148	0	0
150	3	262.5
152	4	350

Time(min)	Notch	Power(HP)
154	4	350
156	4	350
158	1	87.5
160	1	87.5
162	6	525
164	6	525
166	5	437.5
168	0	0
170	5	437.5
172	2	175
174	5	437.5
176	4	350
178	1	87.5
180	1	87.5
182	1	87.5
184	1	87.5
186	0	0
188	0	0
190	0	0
192	1	87.5
194	5	437.5
196	6	525
198	6	525
200	6	525
202	6	525
204	6	525
206	7	612.5
208	5	437.5
210	1	87.5
212	6	525
214	6	525
216	5	437.5
218	6	525
220	5	437.5
222	5	437.5
224	5	437.5
226	7	612.5
228	7	612.5
230	6	525
232	6	525
234	5	437.5
236	6	525
238	6	525
240	6	525
242	7	612.5
244	6	525
246	1	87.5

Time(min)	Notch	Power(HP)
248	0	0
250	3	262.5
252	6	525
254	6	525
256	6	525
258	3	262.5
260	4	350
262	4	350
264	1	87.5
266	3	262.5
268	1	87.5
270	0	0
272	5	437.5
274	6	525
276	5	437.5
278	6	525
280	7	612.5
282	6	525
284	0	0
286	0	0
288	0	0
290	0	0
292	4	350
294	5	437.5
296	5	437.5
298	6	525
300	7	612.5
302	6	525
304	0	0
306	5	437.5
308	5	437.5
310	6	525
312	5	437.5
314	6	525
316	1	87.5
318	0	0

Driving cycle for SHIMLA TO KALKA trip:

Time(Min)	Notch	Power(HP)
0	1	87.5
2	1	87.5
4	5	437.5
6	5	437.5
8	6	525

Time(Min)	Notch	Power(HP)
10	0	0
12	6	525
14	4	350
16	5	437.5
18	6	525
20	0	0
22	1	87.5
24	1	87.5
26	5	437.5
28	6	525
30	4	350
32	5	437.5
34	5	437.5
36	0	0
38	5	437.5
40	6	525
42	6	525
44	6	525
46	6	525
48	6	525
50	5	437.5
52	4	350
54	5	437.5
56	5	437.5
58	0	0
60	1	87.5
62	5	437.5
64	5	437.5
66	1	87.5
68	5	437.5
70	4	350
72	1	87.5
74	5	437.5
76	0	0
78	5	437.5
80	5	437.5
82	6	525
84	5	437.5
86	5	437.5
88	5	437.5
90	5	437.5
92	4	350
94	1	87.5
96	5	437.5
98	1	87.5
100	0	0
102	5	437.5

Time(Min)	Notch	Power(HP)
104	5	437.5
106	5	437.5
108	5	437.5
110	4	350
112	5	437.5
114	1	87.5
116	1	87.5
118	0	0
120	0	0
122	5	437.5
124	6	525
126	7	612.5
128	7	612.5
130	7	612.5
132	6	525
134	6	525
136	5	437.5
138	5	437.5
140	1	87.5
142	0	0
144	5	437.5
146	5	437.5
148	5	437.5
150	5	437.5
152	5	437.5
154	5	437.5
156	5	437.5
158	5	437.5
160	0	0
162	4	350
164	6	525
166	6	525
168	6	525
170	6	525
172	7	612.5
174	0	0
176	0	0
178	0	0
180	5	437.5
182	6	525
184	7	612.5
186	6	525
188	7	612.5
190	5	437.5
192	0	0
194	5	437.5
196	5	437.5

Time(Min)	Notch	Power(HP)
198	5	437.5
200	6	525
202	4	350
204	1	87.5
206	1	87.5
208	1	87.5
210	0	0
212	5	437.5
214	5	437.5
216	5	437.5
218	5	437.5
220	5	437.5
222	6	525
224	1	87.5
226	1	87.5
228	1	87.5
230	5	437.5
232	1	87.5
234	1	87.5
236	6	525
238	1	87.5
240	5	437.5
242	1	87.5
244	6	525
246	1	87.5
248	1	87.5
250	6	525
252	5	437.5
254	1	87.5
256	1	87.5
258	6	525
260	4	350
262	1	87.5
264	1	87.5
266	1	87.5
268	1	87.5
270	1	87.5
272	1	87.5
274	1	87.5
276	1	87.5
278	1	87.5
280	5	437.5
282	1	87.5
284	1	87.5
286	1	87.5
288	1	87.5
290	1	87.5

Time(Min)	Notch	Power(HP)
292	1	87.5
294	5	437.5
296	1	87.5
298	4	350
300	1	87.5
302	1	87.5
304	1	87.5
306	1	87.5
308	0	0

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