FUEL CELL ASSISTED APU SYSTEM FOR DIESEL-ELECTRIC LOCOMOTIVES

OBJECTIVE:

Analysis of the locomotive data has shown that 50% of the run time of the locomotive is spent in IDLING hours only. Unwanted idling of locomotives results in wasteful burning of fuel, oil consumption increased engine wear and tear & increased air and noise pollution by undesirable emissions. The diesel locomotive performs two functions while idling at stand still; the compressor maintains Main Reservoir pressure between 8 to 10 kgs./Sq.Cm and charges the locomotive batteries. However, at stand still with brakes applied, the requirement of air from compressor is less and it is required only to compensate leakage. These two functions do not require much power, however as the full diesel engine runs to cater this requirement, the energy consumed is very large.

A common reason for idling is to avoid difficulty in engine starting and to ensure readiness of engine for immediate use. Idling engine maintains various parameters such battery voltage, air pressure, water temperature.

Fuel cell assisted APU system shall address this situation of unwanted idling of locomotives by automatically controlling the engine shut down and restart operation and at the same time continuously monitoring the existing condition of various parameters vis-à-vis preprogrammed set values and also maintaining those parameters through controls. It shall also be possible to download the recorded data through a commercially available USB pen drive.

Fuel cells are an important technology and have the potential to revolutionize the way we generate power offering cleaner, more-efficient alternatives to the combustion of fossil fuels. Fuel cells have the potential to replace the internal-combustion engine in vehicles.

RDSO has started a pilot project to develop fuel cell assisted Auxiliary Power Units (APU) to be installed in Diesel-electric locomotives of Indian Railways. *The auxiliary* batteries of the APU shall be used to feed power to compressor motor and other auxiliary loads of the locomotive during engine shutdown. During normal conditions when diesel engine is running, *the auxiliary batteries* shall get charged through Auxiliary Generator/companion alternator *of the locomotive* while during loco shutdown the output power of fuel cell stack(s) shall be used to charge the *main batteries and auxiliary* batteries.

1.0 SCOPE:

This document covers the general, operational & performance requirements of Fuel Cell assisted APU system to be installed on diesel-electric locomotives.

2.0 GENERAL REQUIREMENTS:

2.1 Fuel cell assisted APU system shall comprise of as state of the art 32-bit microcontroller system based on minimum and optimum instrumentation architecture with basic feedback components like Current transducer and Pressure switches. It shall be a very reliable architecture and a maintenance free design.

2.3 The system shall operate in three modes namely:

a) Isolation mode

b) Microprocessor based APU mode (Fuel Conservation mode)

c) Intelligent Low Idling mode (ILI)

These modes shall be selectable with the help of selector switch.

2.4 The APU control system shall mainly consists of digital/analog input sensing, execution of the entire control algorithm, releasing commands to the other units, USB port for data logging and GPRS based wireless communication system. It shall also be responsible for ILI of the engine in case the loco crew wishes to operate in the ILI mode.

2.5 The APU control system shall charge the Main reservoir by driving the compressor as and when the commands are received from the controls; in such case the APU shall shut down the main engine.

2.6 The auxiliary batteries of the APU shall get charged from the auxiliary generator/ companion *alternator of the locomotive* whenever the main engine is running. In shut down condition, the batteries shall get charged through the Fuel cell. *During loco shutdown the output power of fuel cell stack(s) shall be used to charge the main batteries and auxiliary batteries. The main batteries shall however get charged only if the battery voltage drops below certain threshold level of voltage (user settable)*

2.7 Online Display of monitored parameters along with the ready reference and quick viewing of all the logged parameters on units LCD Display. The following display is available on LCD with scrolling arrangement:

a) Total Loco/engine Monitoring Timer.
b) Total Time the MBFCS with ILI system was put in MBFCS Mode.
c) Total Time the MBFCS with ILI system was put in Isolation Mode.
d) Total Time the MBFCS with ILI system was put in ILI Mode.
e) Total Engine Start Timer.
f) Total Engine Stop Timer.
g) Total Cumulative Idling Time with engine in start condition.
Idle-A: Idling time of the engine determined by both the throttles in idle position irrespective of reverser position.
II. Idle-B: Idling time of the engine determined by both the throttles in idle position as well as reverser in neutral position.
h) Total number of times loco shut down by the MBFCS with ILI System.
i) Total number of times loco restarted by the MBFCS with ILI System.
j) Number of times loco restarted due to low air pressure (BC and MR) and its mean time of restart.
k) Number of times loco restarted due to low battery voltage and its mean time of restart.
l) Cumulative Shut down time of the engine by MBFCS with ILI system. This parameter depicts the time for which the energy was saved in the form of fuel.
m) Total cumulative time for which the engine was put in low idle RPM of 350 while the MBFCS with ILI system worked in ILI mode.

2.7.1 Recording of status of the engine parameters (Lube oil pressure, Main Reservoir pressure, Brake Cylinder Pressure, Battery Voltage, Battery charging current, etc) on one minute sampling during Idling.

2.7.2 Recording of the total idling time of the engine and the total time for which the engine was shut down by the MBFCS with ILI system (Energy saver timer).

2.7.3 Facility of automatically giving the total fuel saved in terms of litres of diesel saved (wrt MBFCS with ILI Recording of the occurrence of the following events with date and time stamp:

a) Successful shut down of engine automatically by MBFCS with ILI.
b) Successful start of engine automatically by MBFCS with ILI.
c) Successful shut down of engine manually by loco crew.
d) Successful start of engine manually by loco crew.
e) Failed to start engine automatically by MBFCS with ILI.
f) Failed to stop engine automatically by MBFCS with ILI.

2.7.4 Recording of number of time automatic shut down bypassed by driver or loco crew.

2.7.5 Facility of 2-analog and 4-digital input processing and recording facility in addition to above.

2.7.6 The above all the recorded parameters can be easily downloaded by using a commercial USB pen drive unit for easy data retrieval and can be analyzed on any PC through the interactive front end software which is a part of supply of MBFCS with ILI System.

2.7.7 The facility of loco monitoring from a remote location using GPRS. Only a normal internet facility is required for connecting wirelessly to any currently active MBFCS with ILI system on field and viewing its parameters. The user is able to see on an interactive frontend software the following parameters:

1) Cumulative Shut down time of the engine by MBFCS with ILI system. This parameter depicts the time for which the energy was saved in the form of fuel.
2) Total Cumulative Idling Time with engine in start condition.
   Idle-A: Idling time of the engine determined by both the throttles in idle position irrespective of reverser position.
   II. Idle-B: Idling time of the engine determined by both the throttles in idle position as well as reverser in neutral position.
3) Total cumulative time for which the engine was put in low idle RPM of 350 while the MBFCS with ILI system worked in ILI mode.
4) Total Loco/engine Monitoring Timer.
5) Total time the system was put in MBFCS Mode.
6) Total Time the system was put in ISOLATION Mode.
7) Total Time the system was put in ILI Mode.
8) Total engine Start Timer.
9) Total engine Stop Timer.
10) Total number of times loco shut down by the MBFCS with ILI System.
11) Total number of times loco restarted by the MBFCS with ILI System.
12) Image of last event by MBFCS with ILI system w.r.t. time stamp and reason.

Information for point No.1 to 15 shall be available for last 45 days, which the user can view through GPRS interface. This information shall reset automatically when 45 days are over or after 64800 minutes of total loco/engine monitoring timer is over.

2.7.8 Information for point No.1, 2 and 3 also cumulates for last 6 years.
Online status of the following parameters is available on real time basis.

a) Currently MBFCS with ILI - MBFCS/Isolation/ILI mode.
b) Currently Engine- Start/Stop
c) Lube Oil Pressure- High/Low
d) B C Pressure- OK/Not OK
e) M R Pressure- OK/Not OK
f) Battery Current- OK/Not OK
g) Battery Voltage- OK/Not OK
h) Throttle Position- Idle/Non Idle
i) Reverser Position- working/neutral
j) Water Temperature OK/Not OK

The front-end software shall list out all the currently active MBFCS with ILI systems with respect to its serial number Railway zone/Shed name and the type of locomotive in which they are installed. The user shall be able to select the MBFCS with ILI according to his choice to view the parameters as listed above.

3.0 FUNCTIONAL REQUIREMENTS:

The APU system shall monitor parameters including throttle handle positions, reverser position, loco air brake cylinder pressure, main reservoir pressure, battery voltage and battery charging current. Isolating switch shall be provided for driver to isolate the APU system by disabling the APU. A reset switch shall also be provided to the driver to delay the APU from taking over. The reset button when pressed at any stage during idling with the system in APU mode will reset the 10Min count (for shutting down engine).

3.1 Engine shut down conditions: Engine will shut down only when all the below conditions are fulfilled:

- The system is in APU mode
- Both the Throttles are in idle position.
- Reverser in neutral position.
- Locomotive is not moving (logical zero speed =0 kmph) (sensed with the spare potential free speed dependent contacts available in locomotive).
- Battery charging current below 10Amps.
- Main Battery voltage between 67 and 72 volts.
- MR air pressure>6.5Kg/cm^2 and BC pressure>2.3Kg/cm^2
- Engine idling for 10 mins.
- *Auxiliary batteries in healthy condition (to be defined by the tenderer)*
- *Hydrogen pressure in storage*
- *Condition of the fuel cell stack and compressor.*

Audible and Visual warning signal shall be provided to the driver for 15 seconds at 1min interval before shutting down the engine automatically. (Engine driver can bypass the automatic shutdown by pressing Reset button on the front panel of the APU system to count next 10 minutes)

3.2 Engine restart conditions:

a) Engine was shut down by the APU system (No manual shut down)
b) No Shut down of the engine by operation of any engine safety devices.
c) Both the throttle handles in idle position.
d) Reverser in neutral position.
e) Locomotive is not moving (logical zero speed =0 kmph) (sensed with the spare potential free speed dependent contacts available in locomotive).

The APU system shall restart the engine if all the five conditions mentioned above are met along with any of the under mentioned condition:

4) Brake Cylinder Air Pressure <2.0 kg/cm²
5) Main reservoir air pressure is less than 2.1 kg/cm².
6) Battery Voltage less than 62 Volts.
7) The auxiliary battery (APU battery) reaches the under voltage threshold level.

3.3 In addition to the above the APU system shall charge MR so that the air pressure does not go below the threshold limits when the engine is in the shutdown condition. The APU system shall power the compressor *only when* the threshold values of air pressure (MR) is breached. When the auxiliary battery bank reaches its own under voltage threshold level the APU system shall restart the locomotive.

3.4 Engine shall not restart automatically under the below mentioned conditions:

a) The APU system is in Isolation mode.
b) Engine was not shut down by the APU system (manual shut down)
c) Any of the safety trip operated by any of the engine safety device.
d) Throttle handles not in idle position.
e) Reverser not in neutral position.
f) Locomotive is moving (logical zero speed >0 kmph) (sensed with the spare potential free speed dependent contacts available in locomotive).

4.0 INTELLIGENT LOW IDLING OF ENGINE:

In the ILI mode the system will bring the locomotive to low idle rpm of 350 under the following mentioned conditions:

k) Locomotive starts at the normal idle rpm of 400 (idle notch) and runs at this RPM.
l) Lube oil pressure is 1.7Kg/Sqcm or more.
m) No Application of Notching UP, Switching ON of generator field, dynamic braking.
n) These conditions remain stable for five minutes.

The system shall not go for low idling RPM of the engine or shall revert back to the 400RPM idle speed if it was previously running the engine at 350RPM under the following mentioned conditions:

g) Lube oil pressure reduces below 1.2Kg/Sqcmn.

h) Application of Notching UP, Switching ON of generator field, dynamic braking.

4.1 Data logging Feature for ILI:

Following events shall be stored with date and time stamp:

n) Date and time when engine started idling
o) Date and time when engine went in low idling
p) Date and time when engine aborted Low idling mode.
q) Date and time when ILI was bypassed
r) Date and time when ILI was reactivated.
s) Cumulative time of low idling. This time cumulates for six years.

The system shall have a feature to store 5000 such events as mentioned in points (a) to (e).

All the above recorded parameters shall be easily downloaded by using a commercial USB pen drive unit for easy data retrieval and can be analyzed on any PC through the interactive front end software which shall be a part of supply of APU System. Detailed data logging requirements are furnished in para 2.7 above.

5.0 BASIC SAFETY FEATURES

- The APU system shall incorporate suitable interface for complete shutdown of the engine and the same for engine cranking up-to successful starting of the engine.
- Automatic action of APU system shall get disabled if it is put on to 'Isolation Mode' through the front panel switch.
- Pressing the Reset button extends the engine idling time before the automatic shutdown to next 10 minutes (Audio / Visual alarm provided.)

6.0 TECHNICAL REQUIREMENTS:

6.1 Technical requirements of all the major equipment such as auxiliary compressor, battery etc. and controls shall be governed by relevant IEC/International standards. The vendor shall submit design data, characteristic curves & drawings of the equipment to RDSO for approval. The equipment in the APU system shall be designed for high vibration and shunting shock conditions observed in traction application.

6.2 All the important parameters of the fuel cell stack selected such as power, voltage, current, purity, humidification, stoichiometry, pressure drop etc. of fuel & air, stack operating conditions, cooling capacity, emissions, details of controls, weight, size etc. shall be submitted to RDSO. Stack characteristics such as power & voltage vs. current graph shall also be submitted by the vendor.

6.3 The fuel cell shall be based upon /PEM (proton exchange membrane) design. RDSO shall evaluate the various designs based upon commercial availability, maintainability, life cycle costing, type of fuel needed, dimensions/ footprint of the proposed equipment, use in similar applications etc. The proposed cell design should be well shielded against any high internal temperatures and safe to operate and maintain. The efficiency of the cell has to be indicated and shall not be less than value accepted in the industry. The emissions shall be minimal.

6.4 The fuel cell stack(s) shall be based on fuel that may be derived from diesel oil, natural gas, methanol or any other fuel material suitable for use inside diesel locomotives. The power rating of fuel cell stack(s) installed on each locomotive shall appx. 5 KW and it shall be based on latest and proven technology available in the international market.

6.5 The supplier shall furnish a test protocol for the fuel cells and submit the results to RDSO.

6.6 In case the fuel (hydrogen) has to be generated from some other raw material the design of fuel generator should also be furnished in the offer. The fuel generator may be portable and mounted on the locomotive or may be land based wherein the loco can be fuelled periodically. The raw material for generating fuel shall be easily available and the process should be cost effective.

6.7 Alternately, the tenderer may also propose a suitable system for procurement/ refilling of fuel cylinders through agencies already engaged in this work and having a proven track record. The agency shall have to supply refilled cylinders at a defined time and place.

6.8 The system for fuel generation / supply shall be priced separately and shall be considered in evaluation of the overall offer. The firm shall submit an offer from such an agency having proven credentials. This is an optional item and shall be submitted if called for in the tender.

6.6 The firms shall also offer a suitable storage facilities for onboard storage of fuel as well as storage in the lands based fuelling points. The onboard storage shall be enough to store the fuel for atleast 10 days with an average usage of fuel cells for upto 4 hrs per day.

SCOPE OF SUPPLY:

1. BATTERIES: suitable Ni-cd batteries shall be supplied. The total battery capacity shall have to be worked out by the tenderer considering the power requirement of the compressor, fuel cell output, space available on the locomotive etc. the batteries shall be sourced from a reputed and well established manufacturer with a guaranteed service life of at least 6 years.

2. ***FUEL CELL stacks:*** the details provided under are indicative and the tenderer may offer similar or better configuration of fuel cells stacks;

2.1 PEMFC - Proton Exchange Membrane (PEM) Fuel Cells
2.2 Very low maintenance cost (maintenance free for 3 years)
2.3 There shall be no emissions or discharge of any harm full substances such as lead
2.4 etc.
2.5 Shall have a modular construction so that power may be increased easily whenever required.
2.6 Light weight (total weight shall be less than 100 Kg for 3.3KW capacity)
2.7 Requires lass space (1.67 KW x 2 Modules, each in 360 x 446 x 628mm :: HxWxD)
2.8 Protection: IP-55 Class (External to Internal)
2.9 Air Flow: 200 to 600 m^3/h (Internal to External) this airflow arrangement shall be internal to the unit and contained in the proposed dimensions.
2.10 Fuel: Hydrogen (95 to 99%), consumption at 1.74 N m^3/KWh, at Inlet pressure of 5 Bar Full load

3. *Onboard FUEL STORAGE ARRANGEMENT: For* a power requirement of average 1.5 kw of load (consumed continuously on average basis) every day for 8hrs/day, the offered fuel cell system would need (apx.) maximum 10nm3 of hydrogen per day. So for one week of backup

power, the proposed system may require 70nm3 of hydrogen storage, which is a nominal and small size of storage tank would have to be installed onboard. The locomotives can be filled with hydrogen fuel on weekly basis at selected filling stations of Indian railways (to be installed).

In case the proposed fuel cells do not use diesel as the fuel, separate storage shall have to be installed. The tenderer shall quote for the same. The offered storage units shall be compact to fit in existing space on locomotives preferable on top of the locomotive cab. The storage offered shall be adequate for running of the fuel cell for atleast 1week considering an average operation of 8 hours per day. These should be sourced from proven manufactures and must have adequate pressure rating and must comply to relevant international applicable codes and standards including CGA G-5.4 (piping) and G-5.5 (hydrogen vent systems), CGA H-5 (storage) and NFPA 55 and NGV2-1998 standard for pressure vessel qualification.

4. *COMPRESSOR: The compressor shall be oil free design of minimum ----- cfm. The compressor shall be sourced from a reputed manufacturer and shall be maintenance free. The compressor shall take drive from an electric motor of suitable rating, which in turn will be powered from the auxiliary batteries of the APU. The compressor shall not consume more than ----- HP.*

4.0 FUEL GENERATION/STORAGE AND SUPPLY:

4.1 In case the fuel (hydrogen) has to be generated through some process such as Electrolysis etc, the fuel generator should also be furnished in the offer. The fuel generator may be portable and mounted on the locomotive or may be land based wherein the loco can be fuelled periodically. The tenderer shall take complete responsibility for installation and operation of the fuel generator for a period of two years. The raw material for generating fuel shall be easily available and the process should be cost effective.

4.2 Alternately, the tenderer may also propose a suitable system for procurement and refilling of fuel cylinders (h2) through an agency already engaged in this work and having a proven track record. The agency shall have to supply refilled cylinders at a defined time and place. In this case a set up for fuel generation shall not be required. The tenderer shall have to obtain financial quote from such an agency based upon which IR may finalize the work on such a firm.

4.3 The system for fuel generation / supply shall be priced separately and shall be considered while evaluated the overall offer.

4.4 The firms shall also offer a suitable storage facilities for onboard storage of fuel as well as storage in the lands based fuelling points.

4.5 The offered storage units shall be compact to fit in existing space on locomotives (on top of the locomotive cab). The storage offered shall be adequate for running of the fuel cell for atleast 1week considering an average operation of 8 hours per day. These should be sourced from proven manufactures and must have adequate pressure rating and must comply to relevant international applicable codes and standards including CGA G-5.4 (piping) and G-5.5 (hydrogen vent systems), CGA H-5 (storage) and NFPA 55 and NGV2-1998 standard for pressure vessel qualification

5.0 HARDWARE AND SOFTWARE FOR APU CONTROL:

6.0 SOLAR PANEL (optional): this shall be quoted separately in the tender and shall be procured by IR only if found technically and commercially viable over long term.

Maintainability and fitment of solar panels on locomotives is of prime concern and shall govern the decision. Since provision of a separate solar panel shall affect the design and capacity of other subsystems such as controller, fuel cell stacks, battery capacity etc; the tenderers shall give options for both the systems (with and without solar input).

7.0 Service support: the entire system shall carry a warranty of atleast 24 months.

7.1 The successful tenderer shall ensure availability of the entire system to upto 85% for the period of two years and shall put a service engineer dedicated towards maintenance of the APU and shall attend maintenance calls even at short notice.

7.2 The successful tenderer shall also undertake maintenance of the fuel generator (if installed), refueling of the cylinder/ supply of fuel as the case may be.

7.3 The successful tenderer shall also maintain the backend server for a period of two years on which the remote data shall be downloaded and processed.

7.4 *The tenderer must place a full time service engineer exclusively against this project and shall provide to IR details of such an engineer.*

***Evaluation of proposals**: the technical proposals received from the firms shall be evaluated by the indentor and RDSO jointly. Financial bids of only those offers shall be considered suitable that qualify technically. The evaluation shall be done against following criteria:*

- *Design of fuel cell; in terms of commercial availability, proven technology, weight, power output, main ability, life cycle costing etc.*
- *Fuel needed; capital cost of generation of fuel, per unit cost of fuel generation, raw material needed, transportation and storage of fuel etc.*
- *Emissions of the fuel cell*
- *Safety considerations*
- *Other considerations that might come up at the time of evaluation.*
- *Service back up offered by the tenderer.*
- *Size of the equipment offered so as to fit in the available space on the locomotive.*
- *Design of compressor offered etc.*

7.0 Environmental Requirements:

The complete fuel cell assisted APU system shall be modular & compact the preliminary design shall be submitted to RDSO to ascertain the footprint of the proposed equipment. The equipment shall be placed in the locomotive short hood of the locomotive. Relevant drawing of the locomotive can be obtained from RDSO. Vendor shall submit the OGA drawing of the complete system to RDSO for approval before commencement of manufacturing.

- Ambient temperature inside locomotive: 47 ºC (may reach up to 55 ºC)
- Minimum temperature (Atmospheric): -5 ºC
- Humidity: 90% (Up to 100% during rainy season)
- EMC according to EN 50121-3-2
- Vibration and Shock as per IEC-60571
- Encapsulation as per IP54

8.0 DOCUMENTATION

Documents to be furnished are as below:

a) Block diagram of complete system and its interface circuit with locomotive.
b) Circuit description & control logic.
c) Detail specifications for the equipment/fuel cell unit offered.
d) Out line and general arrangement drawing.
e) Maintenance manual with full description of maintenance and repair procedure.
f) Drivers operating instructions and trouble shooting handbook.

9.0 EQUIPMENT FOR TROUBLESHOOTING, MAINTENANCE & TESTING

The firm shall supply special tools along with comprehensive lists for testing, troubleshooting & maintenance of the fuel cell assisted APU system to be supplied by firm. The firm can take the equipment back after completion of field trials and finalisation of control software.

10.0 TRAINING

The firm shall arrange free of cost training to the personnel of Indian Railways in India and abroad to make them proficient in the operation and maintenance of the system and associated equipment providing adequate guidance to enable them to train their subordinate staff in these functions. The to and fro fare and living expenses shall be borne by Indian Railways. Details of the training requirement shall be indicated by the tenderer in its offer.

11.0 SYSTEM INTEGRATION

The firm shall be responsible for the complete system integration of the microprocessor based fuel cell assisted APU system with the excitation/propulsion control system of the locomotive. *The detailed layout of the locomotive is places at annexure-----. Other details regarding the various locomotive subsystems may be obtained from RDSO. The various subassemblies of the offered APU shall have to be suitably placed on the locomotive either onboard or under slung or in a combination of both. The potential vendors may therefore interact with RDSO or the indenter regarding availability and feasibility of mounting such equipment.*

12.0 ACCEPTANCE TEST

Type and routine test schemes shall be prepared in accordance with the relevant IEC/UIC/IS/AAR specifications and furnished to RDSO for approval. Prototype test shall be conducted on the basis of the approved type test scheme in the presence of the RDSO representative.

The inspection and acceptance norms shall be finalised mutually depending upon the type and routine test requirement otherwise frozen. The acceptance norms proposed shall, however, be submitted along with the offer by the supplier.

12.1 Type and Routine Tests

The fuel cell assisted APU system shall be tested for functional test and test programme shall be finalized at design approval stage between firm and RDSO.

Following tests shall be carried out on the prototype unit as per relevant IEC specification or mutually agreed test program. Manufacturer shall bear the expenses of the tests.

SL NO	TEST	CLAUSE	TYPE	ROUT-INE
1.	Visual inspection	As per the approved Drawings	✓	✓
2.	Tolerance & Dimension		✓	✓

3.	Cooling	IEC 60571 clause 10.2.3	✓	
4.	Insulation Resistance	IEC 60571 clause 10.2.9	✓	✓
5.	Di Electric		✓	✓
6.	Vibration and shock	IEC 60571 clause 10.2.11	✓	
7.	Performance test, reverse polarity test, effect of voltage variation test	IEC 60571 clause 10.2.2	✓	✓
8.	Voltage surge	IEC 60571 clause 10.2.6.2	✓	
9.	Electrostatic Discharge test	IEC 60571 clause 10.2.6	✓	
10.	Transient susceptibility test	IEC 60571 clause 10.2.7	✓	
11.	Radio interference test	IEC 60571 clause 10.2.8	✓	
12.	Salt mist test	IEC 60571 clause 10.2.10	✓	
13.	Damp heat	IEC 60571 clause 10.2.5	✓	
14.	Dry heat up to 70 ºC	IEC 60571 clause 10.2.4	✓	
15.	Burn – in	As per Burn-in cycle attached Annexure – 1	✓	
16.	Functional Test	As per test program to be finalized during design approval state	✓	✓

The fuel cell stacks shall be tested as per the relevant test specifications. The stacks shall be designed to withstand a vibration level of upto 3g in all three directions and shock loads of upto 5g. The supplier of the stack shall provide a test certificate towards this.

The following clarifications shall be noted on the tests above:

12.2 Visual inspection of Tolerance & Dimension – The objective of visual inspection is to check that the equipment is free from defects and the equipment is as per approved drawing. Bill of materials shall be submitted. The make, rating of equipment subassemblies shall be checked with the details as per approved design. If a change is needed in make or rating of important equipment, sub-assemblies, it shall be intimated and shall have approval of RDSO. The equipment with modified subassemblies shall be given separate revision number. All the important dimensions shall be measured and shall be in permissible tolerance.

12.3 Insulation resistance and Dielectric test – The insulation resistance with 500 Volt megger shall not be less than 100 M ohms at 70% relative humidity for all the circuits. The dielectric test shall be carried out after earthing special cards if necessary before applying Dielectric voltage. The dielectric test to be carried out at a test voltage of 1.5 kV rms for 60 seconds. The leakage current to be less than 5 mA.

12.4 Burn in test – The cards used on the equipment shall be subjected to burn – in as per the temperature cycle in **Annexure – 1**. The cards shall be kept energized during the test. Functional test of each card shall be carried out after the burn in test. This shall be part of internal test by manufacturer, whose results shall be submitted during routine test.

12.5 Validation test

12.5.1 the complete system shall be tested in the RDSO brake lab where the basic functionality of the system shall be confirmed/ checked. All the sensors etc to carry out these tests shall be supplied by the successful tenderer.

12.5.2 Validation tests like wiring integrity and installation checks, Hi-pot, insulation resistance and self- tests, complete performance establishment, load box examination, parasitic load management verification, track test etc. shall be carried out on the load box at any nominated place mentioned by IR to establish the performance capability and integration of the microprocessor system with other locomotive systems.

13.0 FIELD TRIAL

Extensive field trial shall be carried out on one/ two prototypes or as decided by Indian Railways. The prototypes shall be subjected to field trial for at least 1 month (can be altered by IR) before approval of prototype is granted. During this period, the performance of the equipment shall be closely monitored and evaluated by RDSO. Since this item is a critical safety item, further clearance for limited/bulk supply shall be considered only after extensive field evaluation is conducted. These trials are intended to prove-

- Reliability under rigorous environmental and operating conditions.
- Advantages for locomotive operation and maintenance.
- Maintainability of the equipment.

The supplier shall carry out at his own cost modifications found necessary as a result of the tests, after the relevant modifications have been approved by RDSO.

14.0 SAFETY RELATED MODIFICATION

During implementation of the system, any safety related modifications issued by Indian Railways are to be carried out by the tenderer.

15.0 WARRANTY AND SERVICE SUPPORT

15.1 The supplier shall guarantee the equipment against design and manufacturing defects for a period of two years from the date of commissioning.

15.2 The equipment reliability of the fuel cell assisted APU system should be such that the equipment should be available for a minimum of 85%. (This is percent of the total loco availability, i.e. if the loco is available for 100 hours, the APU equipment should be available for 85 hours minimum). Availability of the equipment shall be monitored by concerned diesel shed through online monitoring system. Any deviation in these criteria shall be personally ratified by the shed in charge.

15.3 20% of the total cost of the equipment should be withheld at the time of purchase and released after 2 years only when the criteria for availability is met.

15.4 As shunting locomotives are deployed to work in yards, the supplier shall arrange to attend the locomotive on the site. Diesel shed may have to make the locomotive available in shed if it is not possible to attend the fault on site.

15.5 Notwithstanding anything that may be specified in this specification, the final responsibility for the suitability of the design shall lie with the supplier who shall undertake to carry out all modifications and alterations to equipment supplied by them for satisfactory functioning in accordance with this specification as may be necessary during the period of two years.

15.6 When the equipment is taken in hand for installation at a nominated shed/workshop/production unit, the supplier shall be responsible for providing all necessary service support and guidance for satisfactory installation and commissioning.

16.0 PACKAGING

i) The component packing must be in assembled form of all the subassemblies. The packing list must totally match the complete bill of material (BOM) to be given by the supplier and this match shall be clearly indicated in the documents accompanying the supply.

ii) The above segments shall be suitably packed to prevent any transit damage. It shall be in line with the standard Indian Railways packing instruction.

17.0 INFRASTRUCTURE FOR MANUFACTURE AND QUALITY ASSURANCE

17.1 Only those firms shall be considered for development of the system that have sufficient experience /expertise in design, manufacture & testing of auxiliary power unit or similar systems (for fuel conservation) related to diesel locomotives. The firm must therefore have thorough understanding of the system and its functionality. Experience in development of fuel cell based systems is desirable. Vendor should furnish their previous supply details / commissioning and feedback in their offer for references.

17.2 The firm shall be having the infrastructure facilities for manufacture and quality assurance as per **Annexure – 2 & 3** (enclosed).

All the facilities are necessary at the time of development and will be verified by RDSO representative.

18.0 SUBMISSION OF TENDER DOCUMENT & EVALUATION CRITERIA:

The supplier/tenderer offering their standard proven product for similar diesel traction application should submit the following credentials with the tender document:

- Printed standard catalogues of the quoted product consisting complete technical details.
- Credentials of supplying the offered product (against the tender items) Reference lists of customer with complete supply and purchase details for the offered product.
- Outline General Arrangement (OGA) and mounting drawings of quoted item. It is desirable that the 3D Uni-Graphics (NX3) model on CD may also be submitted along with the offer.
- Deviation in the technical specifications to be clearly brought in the outstation by tenderer.

The supplier/tenderer who has quoted for the development of the tendered product should submit all the above documents of their similar product to establish their credential (capacity & capability) in manufacturing & supplying the similar capacity item for diesel electric traction application for established railways system.

Qualification of vendors:

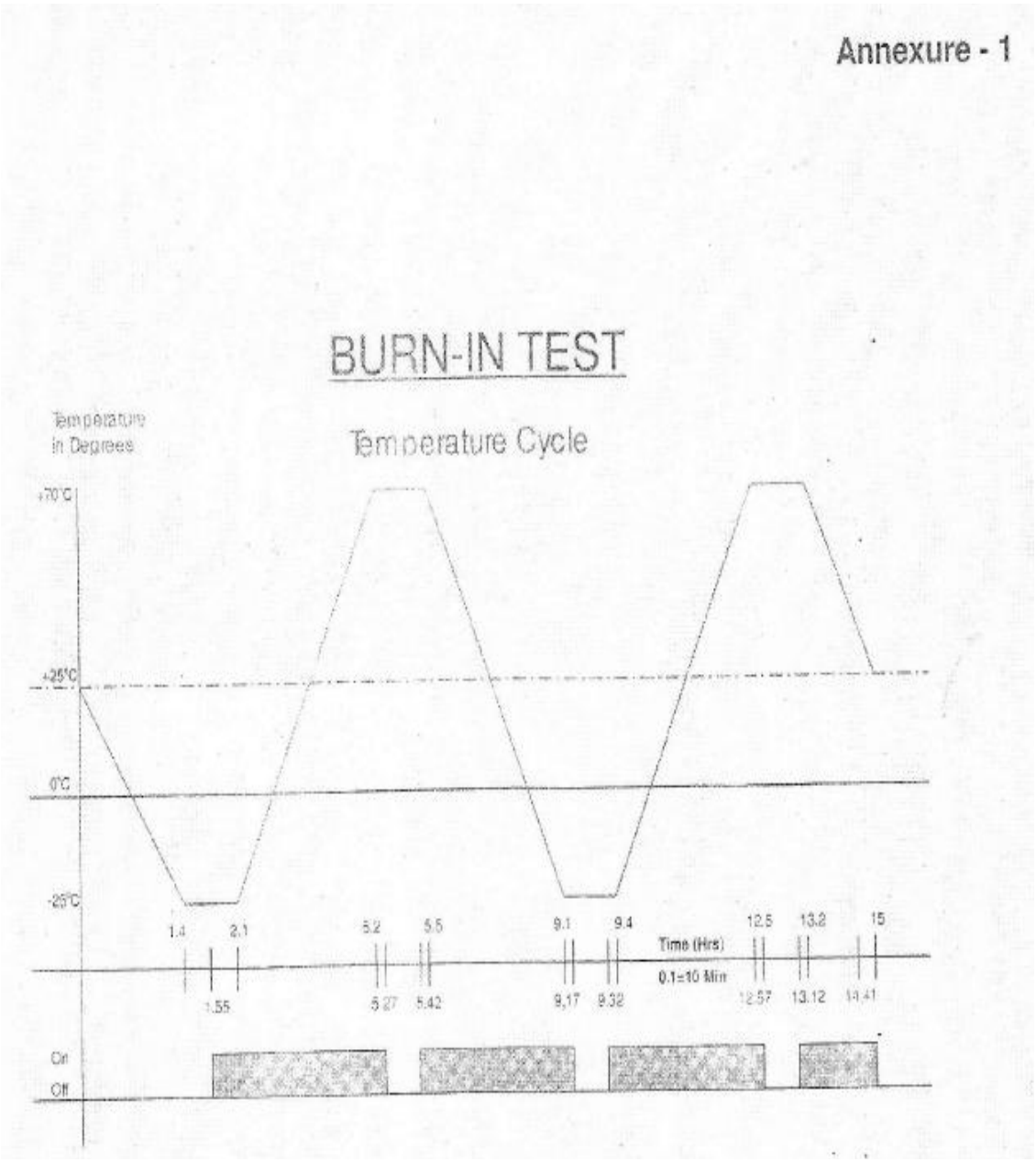
- *The successful tenderer must have all the facilities as mentioned at annexure II and III.*
- *The vendor shall have a proven record of developing and supplying similar locomotive control equipments for application on diesel electric locomotives. Vendors who have*

designed and supplied fuel saving equipments such as ILI/APU/AESS etc with satisfactory performance shall be given preference. Experience in development of fuel cell based systems is desirable. Vendor should furnish their previous supply details / commissioning and feedback in their offer for references.

- *The tenderer must produce an agreement with the fuel stack manufacturer/supplier towards providing service and maintenance support after installation on locomotives.*
- *The successful tenderer shall give an undertaking for providing after sales service in terms of maintenance and maintaining 85% availability for the complete equipment (onboard and off board) during the warranty period.*
- *The successful tenderer must have in house capability to integrate the complete design of the APU. It must have proven software development capabilities, capabilities to develop suitable motor drives, invertors etc. the firm shall substantiate all these by producing past works undertaken. The indenter may also satisfy itself by visiting the works of the tenderer.*
- *This is a fast track project and all the subassemblies / parts of the APU are already available commercially, the tenderer is required to select appropriate equipment and integrate with its control hardware and software. The lad time for delivering the first prototype therefore shall not be more than 3 months. The project has already been published on the RDSO website under EOI for development. Hence the tenderers are expected to finalize the design by the time they submit their offers. The tenderers offering a DP of within 3 months shall only be considered. In case all offers are for DP above 3 months, the tender committee shall take a view.*

Annexure - 1

BURN-IN TEST



ANNEXURE – 2

IN-HOUSE MANUFACTURING FACILITIES

The following facilities are considered essential for the manufacture of quality and reliability product:

1. Dust free environment for the assembly of PCBs
2. Component lead forming machine/fixture for assembly of PCBs.
3. Testing jigs for the testing of assembled PCBs along with measuring instruments for different parameters.
4. Temperature controlled wave-soldering machine with auto-fluxing facilities.
5. Dry heat test chamber.
6. Functional testing of PCBs preferably with computer.
7. Electro static discharge protection in line with IS: 10087-1981. Work procedure for following ESD practices needs to be submitted.
8. Automatic/light beam guided component insertion machine for PCBs or SMD pick and place machine whichever is applicable.
9. In circuit testing machine for checking the correctness of component inserted in PCBs.
10. SMD Soldering station for soldering surface mounted technology component.
11. ISO Certification from NABCB Accredited agency.

All the above facilities are considered essential at the developmental stage and shall be verified by RDSO before considering the firm as a developmental source.

ANNEXURE – 3

TESTING EQUIPMENT

IN-HOUSE TESTING FACILITIES

The following instruments are considered for testing purpose.

1. Power analyser.
2. Storage type oscilloscope.
3. Power factor meter.
4. H.V. Tester.
5. Humidity Test Chamber (for 55°C & upto 95%Rh).
6. Adequate number of Analog/Digital type meters to measure the current, voltage, power and frequency etc. at a particular instant of time.
7. Megger (500Volt).
8. Measuring Gauges such as Vernier Caliper, micrometers, dial gauge, digital stopwatch, Thermometer, thermocouple etc.
9. Digital multimeter.
10. Millivolt meters.
11. Noise/Decibel meter.
12. Testing facility for Water proofness (suitable to dip the entire unit in water).
13. Multi-channel Temperature Scanner (minimum 12 channels).
14. Complete test bench for measuring the different parameters.
15. ISO Certification from NABCB accredited agency.

All the above facilities are considered essential at the developmental stage and shall be verified by RDSO before considering the firm as a development.