



**GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS**

**TECHNICAL SPECIFICATION
FOR
DEVELOPMENT OF ELECTRONIC UNIT INJECTOR (EUI) FUEL SYSTEM
FOR
DLW BUILT 16-CYLINDER 4500 HP EMD 710 G3B LOCOMOTIVES**

**Specification No. TS/ED/2012/65
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**Engine Development Directorate
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1. INTRODUCTION

Indian Railways wants to develop an Electronic Unit Injector System (EUI) for its 2-stroke EMD design 710 G3B engines. At present these engines are fitted with mechanical unit injectors (MUI). EUI once developed, will be retrofitted on the existing MUI equipped locomotive engines and also on newly manufactured engines at DLW. This specification establishes the minimum requirements for the electronic unit injector system. This system is intended to be used for injecting fuel for combustion in the cylinders of EMD-DLW Model 710 diesel engines. Electronic Unit Injectors will be located in the top deck of the engines.

2. SCOPE OF WORK

Bidder shall design, develop and manufacture prototype EUI for the EMD design 710 G3B engines (being used by Indian Railways on their high horsepower locomotives). Bidder will first test the system at their premises to ensure compliance to design parameters. Bidder will then supply the developed EUI system to engine development directorate of RDSO for carrying out its full engine performance, emissions, combustion and endurance testing and ECU calibration. For this purpose bidder will require to develop relevant interfacing hardware and software with the engine test bed controller at engine development directorate, RDSO. EUI developed and supplied by the bidder shall be able to meet the acceptance criteria on the engine development directorate test bed. Acceptance criteria are given in following paragraphs. After successful completion of the test bed trials, same EUI system shall be dismantled from the test bed engine at RDSO and fitted on a locomotive engine at DLW. Locomotive fitted with the EUI system shall be tested on the load box to verify compliance to the acceptance criteria as given in the following paragraphs. After successful load box testing of the EUI fitted locomotive, this locomotive shall be subjected to six months field trials for Reliability Verification Testing (RVT). Any problems (design, manufacturing, operating etc.) arising during the field trials shall be addressed by the bidder in consultation with engine development directorate, RDSO.

3. TECHNICAL REQUIREMENTS

3.1. Proven Design

The EUI system shall be of a proven design. Customization of an existing design to suit the requirements of Indian Railways (IR) is acceptable.

3.2. Mounting Arrangements

The complete system including the electronics and transducers shall be mounted on the engine or in the locomotive cab. During the trial stage on test bed, the ECU and DC-DC converter will be installed in control room.

3.3. Other Design Requirements

To ensure easy fitment, the following restrictions in the design shall apply:

- 3.3.1. The EUI system shall be designed in such a manner, that no major modification to the existing engine shall be required for its fitment. EUI shall be a drop in replacement for the mechanical unit injector.
- 3.3.2. Only minor modifications in the existing locomotive fuel oil circuit shall be required. Any special requirements such as additional/improved filters shall form part of the EUI system.
- 3.3.3. Bidders shall provide design support for any design changes needed on the engine parts to use the EUI system. Fitment of camshaft/crankshaft speed & position sensors shall not require any major design modifications. Sensors for pressure & temperature measurement shall be mounted on the existing lube oil/ water/ air circuit at suitable locations.
- 3.3.4. No leakage/seepage will be permissible in the fuel circuit, EUI system, Check valve etc.
- 3.3.5. Engine Control Unit (ECU) shall be interfaced with the notch signal of the micro-processor control system of the locomotive. Separate provision of hardware/software for the purpose will be part of the system. The ECU shall also be capable of interfacing with the Test cell controllers of the Engine Development Directorate at RDSO. Separate hardware shall be provided for interfacing the ECU with the Test control system at RDSO.
- 3.3.6. Cables of EUI system should be high temperature resistant (upto 300 °C) for example covered with Teflon or other suitable high temperature resistant covering material.

3.4. Safety Requirements

The EUI system, i.e. both the electronic and the mechanical portions, shall be so designed that safety of the locomotive and personnel is not compromised. Following points shall be specifically ensured.

- 3.4.1. There shall be no fire hazard from any type of electrical short circuit.
- 3.4.2. Fuel supply to injectors shall be cut off as soon as the engine stops. This is necessary to prevent fuel oil from dribbling in to the cylinder due to faulty injector operation.

3.5. Redundancy

100% redundancy shall be provided for the sensors and devices whose failure can lead to unsafe operation of the engine. For those sensors, where 100% redundancy has not been provided, a fail-safe, fall-back strategy shall be adopted for all likely failures. Failure of any single component/ sensor/ sub-system shall not lead to a complete shutdown of the engine. Limp home capability shall be built-in.

3.6. Preventive Maintenance

No maintenance including inspection of any type shall be required before 180 days. The bidder shall specify the preventive maintenance schedule required. Care shall be taken by the bidder to ensure that these schedules match the existing locomotive schedules, and the least work content in these schedules shall be preferred.

3.7. Functional requirements

- 3.7.1. **Application** - The injector envelope is defined by the cylinder head for the EMD 710 engine. The envelope is also defined by the space available between exhaust valve bridges. The injector will be held in the cylinder head with a crab.
- 3.7.2. The injector will be supplied with fuel using flexible fuel jumpers made of extruded polytetrafluoroethylene with a continuous conductive path protected by stainless steel braiding. The nominal I.D. of the jumper is 0.406 inches.
- 3.7.3. The fuel system is a through-system, not a dead-end system. Each injector has a fuel inlet and outlet port.

3.7.4. Electronic Unit injector (EUI)

Adjustment Features

- Free adjustment of begin of delivery should be possible within cam related borders depending on engine demand (load and speed).
- Individual control of fuel delivery for each cylinder should be possible.

Emergency Stop

- Immediate stop of delivery by non-energizing of valve to prevent over-fuelling in case of sudden load drop.

Injector Operating Parameters

- The injector will operate in a two stroke cycle engine rated for 4500 BHP at 954 rpm maximum, and idle at 200 rpm.
- The injectors are required to operate to the following parameters listed in Table 1.
- With the solenoid control valve closed, the injector must not lose more than 100 psi fuel pressure in twelve seconds at an initial fuel pressure of 550 psi.

Table 1: Injector performance parameters

PARAMETER	16-710 TURBOCHARGED	G3B
LOCOMOTIVE MODEL	WDG4, WDP4	
PLUNGER DIA (inch)	0.563	
NORMAL OUTPUT (mm³/stroke)	950(1100 MAX.)	
MINIMUM OUTPUT (mm³/stroke)	61	
INJECTION RATE (mm³/crank degree)	55	
STROKE PER MINUTE (Typical rated speed)	900	
STROKE PER MINUTE (minimum rated speed)	200	
STROKE PER MINUTE (max. speed)	1020	
PEAK ROCKER ARM LOAD (lbs)	3500	
PLUNGER STROKE (inch)	0.75	
INJECTION PRESSURE (psi)	14500-17500	
PEAK INJECTION PRESSURE (psi)	18000	
VALVE OPENING PRESSURE (psi)	3100±300	
VALVE CLOSING PRESSURE (psi)	2100-2550	

Injector Calibration

- The injector to injector calibration on new injectors is allowed a variance of $\pm 3\%$.
- Injector must be electronic trim capable with appropriate codes assigned at injector calibration. Calibration codes shall be defined for every 0.5% change in output, with a tolerance of 0.25% for each code.

Injector Spray Tip

- The distance from the cylinder head fire face to apex of the spray tip included angle must be 0.058 ± 0.005 inches.
- The spray tip body is to be identified as to oil flow range by marking of spray tip assemblies within 0.05 L/Min categories.
- The spray tip is to be marked with the number of holes, the diameter of spray hole and the included spray angle. This is required in order to identify the type of the spray tip without disassembly of the injector. For example, a 6 hole with 0.0160 inches spray hole diameter and 150° included spray angle would be marked 6-0160-150.
- Table 2 lists the spray tip configuration

Table 2: Spray tip configuration.

NUMBER OF SPRAY HOLES	SIZE OF HOLES (in.) (ref)	INCLUDED ANGLE ($\pm 2^\circ$)	NEEDLE LIFT (in.) (± 0.003)
6	0.0160	150°	0.018

Injector Grounding

- The resistance from the injector body to either solenoid terminal must be greater than 10 mega ohms.
- The injector must withstand a HI-POT test from injector body to either solenoid terminal of 1500 volts DC for 200 seconds with less than 200 micro amps leakage current.

Injector Electrical Connectors

- The connectors are expected to survive in the environment described in Annexure 5.
- The connector must be designed for injector removal without breaking or cutting of injector wire harness. The connector must be compatible with aEMD P/N 12034222 slotted terminal ring key on the wire harness.

3.7.5. Engine Control Unit

Injectors shall be controlled and monitored by an ECU. Engine Control Unit (ECU) is an electronic device, used to control the start of injection and duration of injection of EUI system as per speed and load condition of the engine. ECU generates analog and digital signals which are used to indicate the engine's operating states but can also serve other purposes and functions. Communication with other units is established via a serial interface and CAN bus protocols. Through a second CAN interface the system communicates with other control systems as well as with diagnostics and monitoring systems. The combination of electronic regulation, governing and monitoring provided by the above components permits to create an engine management system which allows further optimization of the system as a whole.

The ECU should be capable of rapid current energization and de-energization, rise time measurement and fuel calibration. ECU is required for 16 cylinder engine. The injector response time is defined by the change in injector solenoid inductance from open gap to closed gap at valve closure and must be detectable and measurable by the ECU. The response time should fall within the range of 1.12 to 1.54 milliseconds.

ECU is to be fitted in the driver's cab or any other suitable location on the locomotive, the ECU is to be designed for the temperature range of 0°C to 105 °C.

Power supply available on the locomotive is 74V DC, if operating voltage of the ECU is different from this voltage, necessary step-up/step-down device will be the part of the supply.

Functional requirements of the ECU

Variable Injection Timing - ECU should be capable to run the engine on notch-wise variable injection timing as programmed in the map.

Start Quantity Adjustment - For setting start quantity, minimum start quantity or maximum start quantity may alternatively be selected. Furthermore variable start quantity should be provided, by which start quantity is automatically increased during start-up.

Speed Ramps - According to the requirement, speed ramps may be programmed for increasing or decreasing the speed. In addition, a separate speed ramp may be provided for start-up which may make the engine ramp slowly to operating speed after starting.

Variable Set point Adjustment - The set point can be adjusted analogously by

voltage or by current. By means of digital switch inputs, it is possible to change over to fixed speed or to digital synchronizing with speed increase/decrease or to 4-bit control for 16 velocity stages. Change over between the different set point adjustments is possible.

Correction of PID Parameters - To optimize the dynamics of every operating point, the PID parameters may be corrected independently of speed, temperature and load by means of freely programmable stability maps.

Speed Dependent Quantity Limitation - It should be possible to program quantity limitation curves independent of speed so that for all speeds there can be torque reduction as is admissible for the engine or desired by the user.

Over Speed Protection - ECU should be capable to stop the engine, if rpm of the engine goes beyond the predefined engine rpm limit.

Cylinder Equalization by means of Exhaust Gas Temperature

Equalization of cylinder output should be implemented by means of exhaust gas temperature. Exhaust gas temperature is here used as an indicator for cylinder power. Equalization of cylinder temperature aims at equalizing power output of the cylinder. To this purpose exhaust gas temperature of each cylinder should be reported to the ECU. ECU can calculate the average value of the cylinder temperature and correct it by increasing the fuel quantity of the particular cylinder, if found less than the average value.

Boost Pressure Dependent Quantity Limitation

In the locomotive engine, fueling should be reduced to achieve smokeless operation whenever there is low boost pressure in respect to engine notch. The respective limit curves can be programmed accordingly.

Temperature Dependent Idling Speed and Quantity Limitation

At low temperature, the engine can be run at some higher idling speed. With the engine warming up, idling speed is reduced to its normal value. It should be possible to program quantity limitation curves independent of temperature so that for every temperature there will be torque reduction available as is admissible for the engine or desired by the user.

Map Controlled Start of Injection

Start of injection and duration of injection can be programmed by means of characteristic maps. In addition, there is a tuning option on a per cylinder basis. Thereby, optimization of fuel consumption and emission level of the engine is possible.

Oil Pressure Monitoring

For the purpose of oil pressure monitoring, speed/pressure dependent limit curves

should be provided. If oil pressure is low, an alarm is issued, if oil pressure continues to drop, the engine should be shut down.

Sensor Monitoring

If a sensor is faulty, an alarm should be issued and there will be a changeover to emergency operation or an engine shutdown.

Load Regulation System

A load regulation system should be provided, by which generator/alternator output is regulated independent of speed and load.

Configuration of Input and Output Signals

The inputs and outputs should be configured within a wide range according to the requirement.

Click Test

On first commissioning of the engine, the cabling of the solenoid valves can be checked for correctness by a click test.

Data Logging/Error Recorder

At the time of error occurred in the system, data related to cause of error should be recorded in the ECU. This data can be downloaded as and when required.

Communication Port

One Serial Port communication is required to connect the PC/Laptop for parameterization and control the ECU. Communication port should be as per international standard (ISO 9141/SAE J1587 RS 485 upto 9600 baud rate).

3.7.6. Connection Cables

Connection cables should be high temperature resistant up to 800 °C for cylinder temperature sensors and up to 300 °C for other cables. Cables should be covered with Teflon or other suitable high temperature resistant covering material. Necessary coupler, shields, clamps should be provided with the cables.

3.7.7. Sensors

The following type of sensors will be used in the EUI system to monitor the various parameters of the engine. Details of the sensors are given below-

Speed and Cam Position Sensor (Hall Sensor)

Speed and position sensor (hall sensor) will be used to monitor the engine rpm and the correct position of camshaft. According to this input of the hall sensor, ECU can calculate the start of injection and duration of injection and send the signal to the EUIs. Two speed and cam position hall sensors for each loco will be required for reliability purpose.

Boost Air Pressure Sensor

Boost Air Pressure (BAP) sensor is required to monitor the boost air pressure of the engine. Measuring range of the sensor should be 0-5 bar.

Lube Oil Pressure Sensor

Lube oil pressure sensor is used to monitor the lube oil pressure of the engine. Measuring range of the sensor should be 0-10 bar.

Coolant Temperature Sensor

Coolant temperature sensor is required to monitor the coolant temperature of the engine. Measuring range of the sensor should be -50 °C to 150 °C.

Exhaust Gas Temperature Sensor

Measuring range of the sensors will be 0-800°C.

Crank case vaccum monitoring Sensor

Crank case vaccum monitoring sensor is required to monitor the vaccum inside the crank case. If crankcase vaccum goes beyond the normal range, engine should be stopped immediately. Measuring range of this sensor should be (-300 m bar to 300 m bar).

Apart from the above, any other sensor required to run the system efficiently will be part of the supply.

3.7.8. Interfacing Device

Interfacing device will be required to interface the Engine Control Unit (ECU) of the EUI system with the test commander PUMA OPEN of engine test bed at Engine development Directorate and with the microprocessor control system of the EMD locomotive. Details of the interfacing are given in Annexure-3.

4. ACCEPTANCE CRITERIA

- (i) Bsfcr reduction- 2-2.5 % reduction over IR duty cycle vis-a-vis existing MUI system.
- (ii) Reduction in particulates and smoke emissions by 25% as against existing MUI system.
- (iii) No increase in the NOx emissions in comparison to existing MUI system.
- (iv) Noise reduction over existing MUI system as perceived by human ear
- (v) Should have cleared million cycle test on test rig at Bidders premises in non-firing high temperature condition.

5. DELIVERABLES

One loco set of EUI system normally comprise of the following, However bidder will have to provide bill of material as per their design indicating quantities of each item.

S.No.	Description of Items	Qty
1.	ECM-Control box	01 loco set
2.	Diesel Electronic Injector	
3.	Unit exchange Diesel Electronic Injector	
4.	EUI wire standoff (grabe iron type)	
5.	EUI wire standoff (upright w/rod)	
6.	End plate, block to harness bulkhead connector	
7.	Injector harness with grey connector	
8.	Injector harness with black connector	
9.	Mail sensor-injector harness	
10.	Power harness	
11.	Temperature sensor, Air box and Engine oil	
12.	Pressure sensor, Engine cooling water	
13.	Oil pressure sensor	
14.	New CCP and TBS housing	
15.	TDC & RPM sensor	
16.	Electronic Control Module mounting plate for AC cabinet	
17.	Fuel rail bracket (pair) with bolt, lock nut, flat washers, copper washer	
18.	TDC and RPM bracket spacer	
19.	Fuel Rail gasket (end side)	
20.	Fuel Rail Assy, left	
21.	Fuel Rail Assy, right	
22.	TDC and RPM sensor mounting bracket	
23.	Orifice for injector return lines	
24.	Orifice for injector supply lines	
25.	Pressure relief valve (installed in outer sight glass)	
26.	Pressure relief valve (installed in inner sight glass)	
27.	Gasket, harness end plate for sealing EMD block	
28.	Fuel Rail gasket (block side)	
29.	Wiring harness bulk head connector	
30.	Oil temperature sensor bracket	
31.	Bracket, sensor junction box	
32.	Gasket, oil temp sensor bracket	
33.	Sensor, Junction box assy.	
34.	Governor drive cover plate	
35.	Governor drive cover plate gasket	
36.	Communication port & bracket assy.	
37.	Timing pin	
38.	Oil pressure sensor block	
39.	CCP housing Gasket	
40.	Sensor mounting Adapter	

* DC-DC converter can be integrated into the same envelope as the ECU

6. TECHNICAL DATA& DRAWINGS

A complete set of technical data and drawings to support the claims of the bidder regarding the design, fitment, maintenance, operation, performance, etc. shall be supplied with the offer. Some of the specific data to be supplied are:

- 6.1.** Detailed technical specifications of the system.
- 6.2.** Complete dimensioned diagram of the system.
- 6.3.** Material specification of critical components.
- 6.4.** Complete dimensioned installation drawings.
- 6.5.** Installation, maintenance and operating instructions, part Catalogue and tool catalogue.
- 6.6.** Details of test rigs used by the Bidder to establish parameters.
- 6.7.** Details of earlier applications of the system on similar engines or engines of similar power output or used on diesel locomotives of similar bore, engine speed and power output.
- 6.8.** Details of special tools and rigs required for the maintenance of the
- 6.9.** EUI system.
- 6.10.** Complete details of the entire software and User manual.
- 6.11.** Source code of the software may be quoted as an optional item.

7. PRE-DESPATCH INSPECTION

- 7.1.** Design and process failure mode and effect analysis (FMEA) are required for the injector. These must be provided to the IR team prior to their visit to the bidders works.
- 7.2.** The reliability goal for the injector is 0.18% failures per year (equates to 0.029 failures/ 16 cylinder locomotive/ year). The failure rate should remain constant during the life of the injector. The bidder should design and manufacture the electronic unit injectors with the above reliability goal.
- 7.3.** The responsibility for design qualification testing of EUI, ECU etc. shall be with the successful bidder. Documentation verifying the successful completion of qualification test shall be provided to RDSO Engine Development Directorate personnel for review during the IR team visit to the bidder works. Bidder shall offer the relevant specifications of each equipment for testing the offered equipment. The inspection and routine test procedure shall be offered to RDSO for approval before commencing manufacture.
- 7.4.** The offered equipment shall be inspected on the test rig at the successful

bidders premises by RA/Berlin for establishing the performance characteristics of the system. Once qualification approval has been granted, the successful bidder must not implement any changes in design, materials, process or location of Bidder or test, without written approval from Engine Development Directorate, RDSO.

8. PERFORMANCE TEST ON ENGINE TEST BED AT RDSO

Before fitment of EUI system on locomotive, the specified performance shall be validated on the test bed of Engine Development Directorate, RDSO, Lucknow, by first generating baseline data with the existing Mechanical Unit Injector System and then with the supplied EUI system. All other engine components shall be kept identical.

9. PERFORMANCE TEST ON LOCOMOTIVE (Field Trial)

- 9.1.** After the validation of the system performance on RDSO test bed, the system would be fitted on a locomotive. After proving out the functional requirement on the locomotive, its performance regarding maintainability and reliability under field conditions would be jointly monitored by RDSO and the Bidder for 6 months. This can be extended if required. All problems noticed during this period shall be logged and a satisfactory solution shall be found.
- 9.2.** It is for the guidance of the bidder that the reliability goal for the EUI is 0.18% failures per year (equates to 0.029 failures/ 16 cylinder locomotive/ year). The failure rate should remain constant during the life of the injector.
- 9.3.** Any modification, including change in the software of the EUI System, arising out of prototype fitment and testing shall be done by the supplier free of cost.

10. TRAINING

The bidder shall be willing to train five IR personnel for two weeks in the new technology at the time of prove-out on engine test bed.

Annexure-1**ENGINE DESIGN DATA- GM-EMD-710G3B**

1. Engine Geometry:

1.	Bore (mm)	230.19
2.	No. of stroke	2
3.	Stroke (mm)	279.40
4.	Weight of piston	27 Kg.
5.	Length of connecting Rod (mm) centre to centre	584.2
6.	Compression Ratio	16:1
7.	Number of Cylinders	16
8.	Wet or Dry liner or parent Bore	Wet
9.	Configuration	45 V
10.	Firing order	1,8,9,16,3,6,11,14,4,5,12,13,2,7,10,15,

2. Engine Performance Data:

1.	Power	4500 HP
2.	Speed	954 rpm
3.	Max. Cylinder Pressure	108 bar
4.	Air Consumption	6.0 kg/sec
5.	Ambient (PAMB)	1.0 bar
6.	Inlet Manifold (after compressor) (PACO)	1.25 bar
7.	Turbo rpm	18150
8.	Exhaust temp Inlet To Turbine	535 ⁰ C
9.	Exhaust temp. outlet from turbine	419 ⁰ C
10.	Fuel pressure	4.3 bar
11.	Lube oil pr. In	7.21 bar
12.	Lube Oil pr.RE.	3.97 bar
13.	Piston cooling pr.	5.32 bar
14.	Lube Oil Cooler out let Temp.	78.5 ⁰ C
15.	Lube Oil Cooler Inlet Temp.	90.1 ⁰ C
16.	Plunger dia of MUI	14.2 mm
17.	Number of holes in Nozzle	6

3. Valve Data:

1.	Timing EVO	103 degree ATDC
2.	EVC	61 degree ATDC
3.	Air Intake Port Open	45 ⁰ Before BDC
4.	Air Intake Port Closes	45 ⁰ After BDC
5.	No. of Exhaust valves/cylinder	4

4. Exhaust Manifold Data:

1.	No. of cylinder discharging in to one turbine entry pipe	16
2.	Firing interval of cycle discharging in one turbine entry	22.5 degree
3.	Exhaust manifold volume / Turbine entry	-
4.	Number of entries / Turbine	Three

Annexure-2**Engine configuration**

1.	Engine	16 cylinder GM-EMD-710G3B Make Diesel Engine
2.	Turbo	GM-EMD-02-J1-1066 Turbocharger (Air-cooled)
3.	Piston	GM-EMD(16:1)
4.	Ring pack	M/S GM-EMD
5.	Manifold	Stream line single entry
6.	After cooler	Twin after cooler
7.	Camshaft	GM-EMD, Over hung
8.	Fuel oil	HSD oil Euro IV of M/s Indian Oil Corporation
9.	Lube oil cooler	Young Touch stone make,(9560308)
10.	Lube oil	RR 520 Multigrade Oil of M/s Indian Oil Corporation
11.	Fuel injection pump	Mechanical Unit injector supplied by M/s Interstate Diesel, USA.

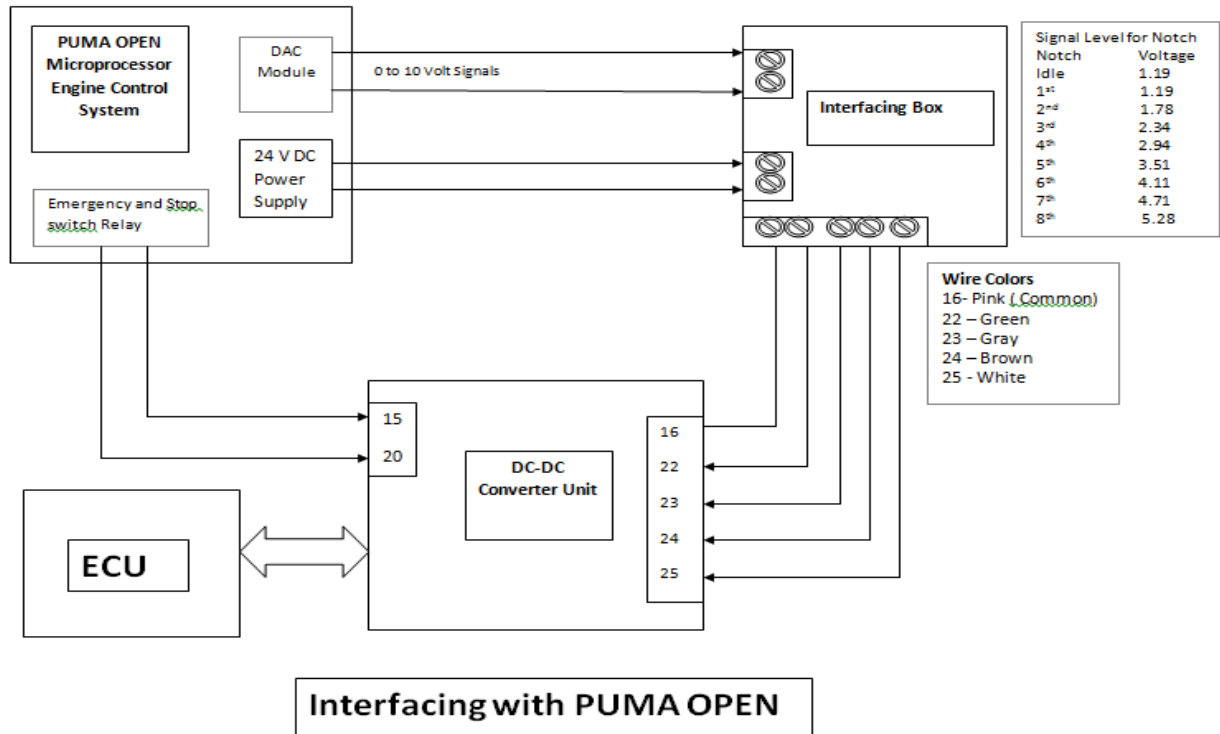
Annexure-3

Interfacing of ECU with Test Commander of EMD engine (AVL PUMA OPEN)

In the present Mechanical Unit Injector (MUI) system, two fuel control shafts are actuated by the engine actuator using servo motor drives. These control shafts control the rotational movement of the plungers of the MUIs. This rotates the helix of the MUI plunger and changes the effective stroke and delivered fuel quantity. The PUMA OPEN operating system of the test bed controls the engine load by hydraulic dynamometer and speed control through fuel rack.

In the EUI system, fuel delivery of the EUIs will be controlled by ECU through solenoids of the EUIs and feedback from the various sensors i.e., speed and position, lube oil pressure, boost air pressure and engine water temperature etc. will be monitored by the ECU. ECU will be connected to the PC/laptop for controlling/optimizing the important parameters of the engine. An interfacing device will be required to interface the ECU of EUI system to the test commander AVL PUMA OPEN of the test bed.

The block diagram of the interfacing of ECU with test commander AVL PUMA OPEN is shown below-



Present Interfacing of microprocessor control system of EMD locomotives with engine governor

At present, the engine governing on EMD locomotives is carried out by Woodward, Siemens or EMD make governors. The basic function of the governor is to control the speed of the engine, based on throttle handle position (notch). The secondary function is to control the load on the engine electrically, through an interface with the Microprocessor Based Control System (MBCS). This maintains a preset constant horsepower at each notch position. In addition to these functions, the governor functionalities also include air manifold pressure based fuel limiting, low crank case vacuum shutdown, hot engine water and low lube oil pressure shutdown.

When driver notch up the engine, notch signals are transferred from MBCS to Engine Governor through GVA, GVB, GVC and GVD wires and LCR (Load Control Rheostat) signal is transferred from engine governor to MBCS through 3 wire i.e, LR. LCR signal range is from 72 V to 0 V. In normal condition of the engine (under-loaded or optimally loaded), the LCR voltage is 72Volts, when the engine is overloaded, the LCR signal will vary to maintain the engine rpm by increasing the LCR voltage up to a maximum limit of 0 volts.

Present system of interfacing of the engine governor to the MBCS of EMD engine is given below-

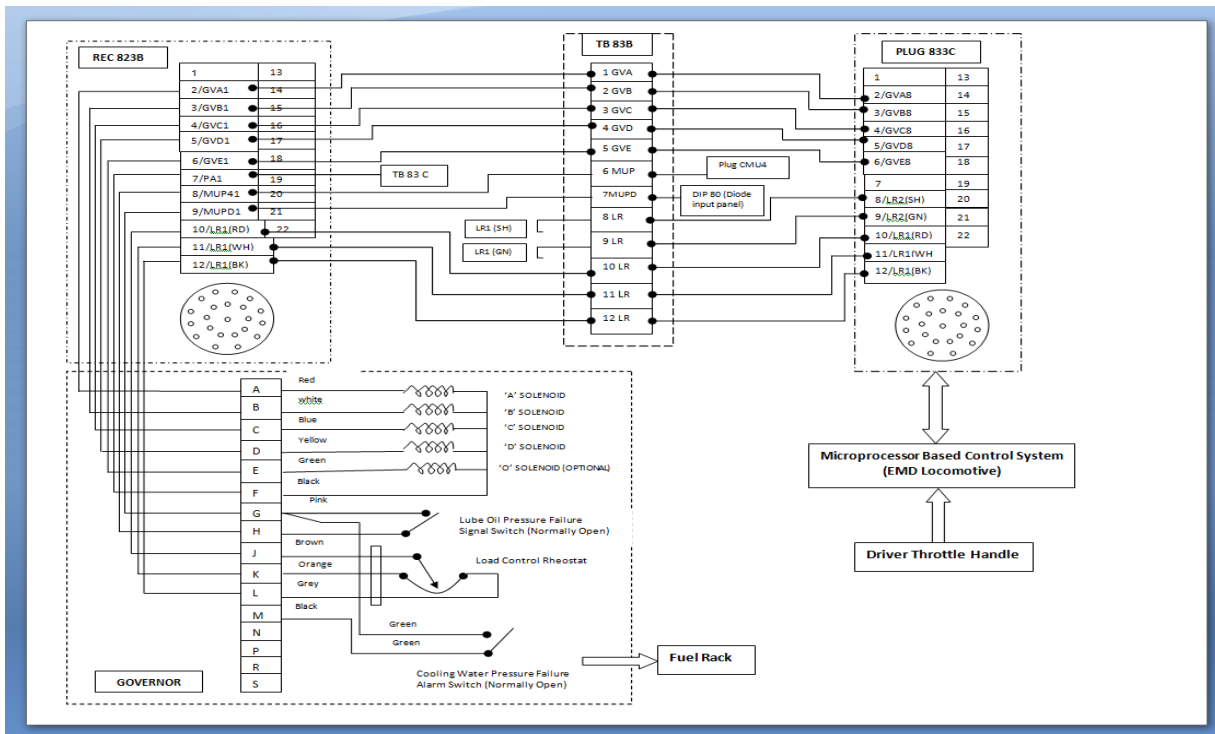


Figure: Present interfacing of MBCS of locomotive with engine governor

Proposed Interfacing of EUI system with microprocessor controlled EMD locomotive

Block diagram of proposed interfacing of EUI system with the microprocessor control system of EMD locomotive is given below. 74V DC supply from the locomotive battery bank is given to DC-DC converter through MCB installed onto the DC-DC converter box. Engine notch signal in form of four bit binary signal (through four wires) from the MBCS through locomotive terminal board is given to the ECU interface box, which goes to the ECU for further processing. Microprocessor based control system in EMD locomotive is an AC-AC traction control system. It supports standard SAE J1708 which utilizes hardware RS 485 transceivers. Communication protocol with ECU will be mutually worked out in consultation of OEM of traction control system.

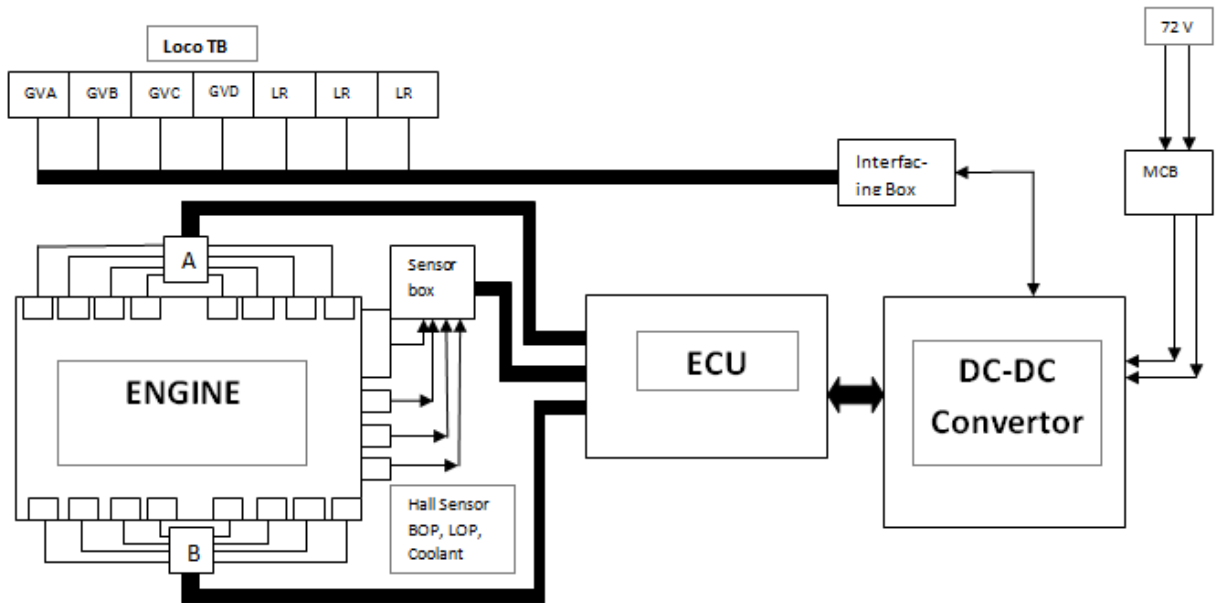


Figure: Proposed interfacing diagram of EUI system of EMD engine

GENERAL REQUIREMENTS FOR GUIDANCE OF THE BIDDERS

Expected Life - The electronic unit injector is expected to last for the life of the power assemblies, which is currently five to six years in mainline freight service. Minimum life is three years, which would require an injector replacement between engine overhauls.

Materials - Materials under normal use shall produce no toxic gases and be self-extinguishing.

Component Selection - Components selected for use in this device shall be such that the Bidder shall have design freedom to modify components in response to changing operating environment or performance requirements, or in response to field reliability or durability problems.

Labeling - The electronic unit injector shall be identified with a coded date, unique serial number and calibration code .

ENVIRONMENTAL REQUIREMENTS

Operating Temperatures - The injector is required to operate from -40°F to 250°F (300°F) soak in the engine top deck. The maximum temperature exposure of the injector spray tip is 800°F.

Cooling - The injector will be cooled with excess fuel flow and by engine jacket water in the cylinderhead. The cylinder head temperature is not expected to exceed 550°F. Solenoid valve of the EUI is to be cooled by the diesel fuel circulated through the solenoid valves.

Lubrication - External lubrication of the injector must be accomplished using splash oil from the engine top deck. Internal lubrication of the injector must be accomplished using diesel fuel.

Diesel Fuel Properties - Diesel fuel will conform to IS 1460 latest revision. The injector must be able to operate with minimum system supply pressures of 75 psi at rated load and 100 psi at idle. The injector is required to operate with transient fuel supply temperatures ranging from -15°F to 160°F at the injector. Primary filtration of the diesel fuel is 11-14 microns at 90% single pass efficiency with secondary filtration of 5 microns at 90% efficiency. The required minimum fuel flow through the injector is 0.361 gallons per minute per cylinder at nominally rated load for the model 710 engine, which represents a factor of 1.6 the amount required for combustion at rated load and speed. There is no water separator in fuel system.

ENGINE MODEL	710 GB / GC
CONSUMPTION AT RATED LOAD AND SPEED (GPM/INJ)	0.226 (0.351 MAXIMUM)
REQUIRED FLOW (GPM/INJ)	0.361 (0.402 MAXIMUM)

Locomotive Car-body Acceleration - The injector will operate in an environment with the following accelerations (based on locomotive car-body accelerations):

Injector longitudinal axis 3.0 g

Injector vertical axis 1.5 g

Injector lateral axis 2.0 g

Typical Indian Railways Operating Duty Cycle for Diesel Locomotives

Notch	Freight Service (%)	Passenger Service (%)
Idle	60	49
1	3	6
2	5	7
3	3	5
4	4	4
5	4	7
6	5	5
7	6	5
8	10	12

Extracted from RDSO report no.- MP.Misc.-204 of Feb.2008

Storage - The injector is required to withstand ambient temperature storage form -40°F to 105°F. The injector is required to have a corrosion free shelf life of six months.