Issued by:	**ENGINEERING DESIGN PERFORMANCE SPECIFICATION**	No: TS/ED/2013/3
Approved by:	Engine Development Directorate Research Designs and Standards Organisation, Manak Nagar, Lucknow	First issued: May-2013 Supersedes:
Subject	Engine Control Unit (ECU) with associated accessories	
Affects Models	DLW built 16 cylinder 3100/3300/3600 hpALCo locomotives	
Ref. Drawings		
Originator		
Supplier	The following information is the property of Engine Development Directorate of Research Designs and Standards Organisation, Manak Nagar, Lucknow and must be treated as privileged communication between suppliers and Indian Railways	

1. INTRODUCTION

Engine Control Unit (ECU) is an electronic device, used to control the start of injection and duration of injection of Electronic Fuel Injection (EFI) pump as per speed and load condition of the engine. ECU generates analogues and digital signals which are used to indicate the engine's operating states but can also serves 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.

2. GENERAL OPERATING CONDITION

2.1 Environment

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

3. EXPECTED PERFORMANCE

3.1 Maximum acceptable failure rate in two years, including all failure modes is 0.25%.

4. FUNCTIONAL REQUIREMENTS

4.1 Variable Injection Timing

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

4.2 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.

4.3 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.

4.4 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 adjustment is possible.

4.5 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.

4.6 Speed Dependent Quantity Limitation

It should be possible to program quantity limitation curves in dependence of speed so that for all speeds there can be torque reduction as is admissible for the engine or desired by the user.

4.7 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.

4.8 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.

4.9 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 in dependence of temperature so that for every temperature there will be torque reduction available as is admissible for the engine or desired by the user.

4.10 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.

4.11 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.

4.12 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.

4.13 Load Regulation System

A load regulation system should be provided, by which generator output is

regulated in dependence on speed and load.

4.14 Configuration of Input and Output Signals

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

4.15 Click Test

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

4.16 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.

4.17 Control Solenoid of Electronic Fuel Injection Pump

ECU should be able to control the solenoids of the EFI Pumps of the following characteristics-

1.	Operating Voltage	24V DC
2.	Voltage Range	16-33V DC
3.	Pull in Voltage	5.56 V
4.	Boost Current	12A
5.	Hold Current	5-10A
6.	Free air Inductance	0.410 ± 0.06mH
8.	Winding wire	0.643mm (Bare wire)
9.	Flying Time	0.8 ms
10.	Temperature Range	-40 to 125 °C
11.	Protection Grade	IP 66K

5. DESIGN SPECIFICATIONS

5.1 Engine Control Unit (ECU)

Engine Control Unit (ECU) of the EFI system shall take over all the functions of the existing governor of the locomotive. Supplied ECU and associated accessories will be fitted with EFI pumps 16mm or more plunger dia. Technical details,inputs/outputs of the ECU are given below-

S.No.	Parameters	Details
1.	Operating Voltage	24 V DC
2.	Minimum Voltage	18 V DC
3.	Maximum Voltage	33 V DC
4.	Residual ripple	Max. 10% with 100 Hz
5.	Output Voltage for solenoids	24V DC
6.	Current consumption	Max. 0.5A per cylinder and max. 24A for 2ms

7.	Storage Temperature	-55 to 105 ^{0}C
8.	Ambient Temperature	-40 to 80 ^{0}C
9.	Air Humidity	Up to 98% at 55 ^{0}C
10.	Contamination	Resistant against substances typically present in the engine environment
11.	Vibration	Max. 9g with 64-2000 Hz
12.	Shock	50g, 11 ms, Half Sine Wave
13.	Protection Grade	IP-65
14.	Isolation resistance	>1MOhm with 48V DC

5.1.1 Inputs and Outputs

All inputs and outputs arereverse polarity proof and short circuit proof against battery positive and battery negative. Inputs and outputs of ECU is given below-

S.No.	Parameters	details
	Input Signals	
1.	2 speed sensor inputs	Hall sensors with 25-8000 Hz
2.	3 Temperature Inputs (Lube oil temp., Fuel Oil Temp. and Coolant Temp.)	PT 1000/PT-100
3.	16 High Temp. Inputs for Cylinder Head Temp.	'K' Type Thermocouple
4.	3 Pressure Inputs (Boost Pressure, Oil Pressure and Fuel Oil Pressure)	Pressure Sensors (0-10 bar)
5.	4 bit Notch Signals (digital)	0-72V
	Output Signals	
6.	16 Solenoid Valves drives	I<6A, I<25A for T <2mS, 24V DC Pulse Width Modulation
7.	LCP signal	24-68V

5.1.2 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)

5.2 Dc-Dc Convertor

Power supply available in the locomotive battery bank is 72V DC and the input supply requirement of the ECU is 24V DC, therefore a DC-DC convertor is required to step down the power supply to suit the ECU inputs.

5.3 Connection Cables

Connection cables should be high temperature resistant up to 800 $^{\circ}$C for cylinder temperature sensors and up to 300 $^{\circ}$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. Details of

the cables are given below:-

S.No.	Description of cables	Approx. length of cables**	Qty. required for one loco set
1.	Cable from ECU to left and right bank of EFI pumps	14 meter	02 no.
2.	Cablesfor all sensors (a) ECU to Speed and position sensor (b) ECU to Lube Oil Pressure Sensor (c) ECU to Coolant Temp. Sensor (d) ECU to Boost Air Pressure Sensor (e) ECU to 16 no. Cylinder Temperature Sensors	 10 meter 2 meter 18 meter 10 meter 14 meter	01 set.
3.	Cable from ECU to DC-DC convertor	2 meter	01 no.
4.	Cable from interfacing box to loco terminal board	6 meter	01 no.
5.	Cable from Dc-Dc convertor to interfacing box	2 meter	01 no.
6.	Cable from ECU to USB drive of PC/Laptop	4 meter	01 no.

**** These lengths will vary according to the wiring harness layout.**

5.4 Sensors

The following type of sensors will be used in the EFI system to monitor the various parameters, details of the sensors are given below-

5.4.1 Speed and Cam Position Sensor (Hall Sensor)

Speed and position sensor (hall sensor) will be used to measure the engine rpm and to monitor 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 EFI pumps. 02 no. hall sensors for each loco set will be required for reliability purpose. The details of the sensor are given below-

S.No.	Parameters	Details
1.	Length of sensor including coupler	110 mm
2.	Length of threaded portion	76mm
3.	Type of thread	M 18X1
4.	Switching frequency	1 Hz-16000 Hz
5.	Air gap	0.5mm – 2mm
6.	Supply Voltage	8 – 33V
7.	Output	Push-pull
8.	Signal shape	Square-Wave

9.	Pull up	1 K Ohms
10.	Operation temperature range	-40^0C to 125^0C
11.	Protection	IP 65
12.	Vibration	<10g (10Hz-100Hz)
13.	Shock	<50g

5.4.2 Boost Air Pressure Sensor

Boost Air Pressure (BAP) sensor is required to monitor the boost air pressure of the engine. The details of the sensor is as under-

S.No.	Parameters	Details
1.	Measuring Range	0-5 bar
2.	Over pressure	10 bar
3.	Supply Voltage	9-32 V DC
4.	Output Signal	4- 20 mA
5.	Operation temperature range	-40 ^{0}C to 125 ^{0}C
6.	Protection	IP 65
7.	Vibration	<15g (20 -2000Hz)
8.	Shock	<50g

5.4.3 Lube Oil Pressure Sensor

Lube oil pressure is used to monitor the lube oil pressure of the engine. The details of the sensor is given below-

S.No.	Details	Details
1.	Measuring Range	0-10 bar
2.	Supply Voltage	9-32 V DC
3.	Output Signal	4- 20 mA
4.	Operation temperature range	-40 ^{0}C to 125 ^{0}C
5.	Protection	IP 65
6.	Vibration	<15g (20 -2000Hz)
7.	Shock	<50g

5.4.4 Coolant Temperature Sensor

Coolanttemperature sensor is required to monitor the coolant temperature of the engine. The details of the sensor is as under-

S.No.	Details	Details
1.	Measuring Range	-50 ^{0}C to 150 ^{0}C
2.	Supply Voltage	9-32 V DC
3.	Output Signal	4- 20 mA
4.	Protection	IP 65
5.	Vibration	<20g (10 -300Hz)
6.	Shock	<50g

5.4.5 Exhaust Gas Temperature Sensor

S.No.	Details	Details
1.	Length of sensor	100mm
2.	Dia. Of sensor	8mm
3.	Length of threaded portion	22mm
4.	Type of threads	Tapered (dia.20.8mm to 20.3mm), 1.5mm pitch
5.	Measuring Range	0-800 ^{0}C
6.	Protection	IP 65
7.	Vibration	<60g (10 -100Hz)
8.	Shock	<50g, 11ms Half Sine

6. PRODUCTION INSPECTION FOR QUALITY ASSURANCE

The method of inspection and sample size shall be arrived at by mutual negotiations between the supplier and Indian Railways's quality control department and vendor quality assurance committee. All test procedures called out on any applicable Engineering Test Instructions must be followed.The manufacturer to indicate applicable engineering test instructions for their equipment.