Reasoned document for "Development of Electronic Unit Injector (EUI) system for DLW built 16 cylinder EMD 710 G3B locomotives" as per Technical specification no. TS/ED/2012/65, Rev.-2 of July-2014

S. No.	Clause no. of Technical Specifications	Description of clause	Comments of M/s AIKON Technologies pvt. Ltd. on RDSO's specifications	RDSO's remarks	M/s AIKON's remarks on RDSO's comments	RDSO's comments on M/s AIKON's remarks	Final clause after modification
1.	Clause no. 3.7.4 Electronic Unit Injector (EUI)	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.	This point is confusing. With the control valve closed, pressure is bypassed from the body & plunger which is the area you would actually want to check for leakage.	It is stated that the basic idea behind this point is to check the leak off rate of the EUI system, when solenoid valve is closed. Reference clause no. 5.2.3 of EDPS no. 502 of May 1977 of Electronic Unit Injector for EMD 710 engines. How do M/s Interstate propose to address this checking of leakage in closed condition of solenoid valves.	Interstate Diesel checks the leak off rate in an EUI without closing the solenoid. We connect a pump to the fuel hoses and run fuel through the injector until all bubbles have cleared up. The valve on the return hose is closed and pressure is raised to 200 psi. After waiting 5 minutes at this pressure, we observe if there is any visible leakage between the nut and the body, stator spacer, the 2 body plugs and the area under the follower spring (which checks plunger to body leakage). Pressure must be maintained during this test between 150 and 200 psi. After this 5 minute test the pump is again actuated to raise the internal pressure to 350 psi and turned off. A timer is started when the pressure reaches 300 psi. Acceptable pressure drop after 1 minute is 80 psi. We electrically energize	Different testing procedures are adopted by the different firms for the testing of the injectors. Generalized clause must be kept to address this issue.	OEM must specify its protocol for leakage testing of injector.

					the solenoid control valve until closed, only to perform a 40 strokes per minute pop test. The injector must produce a sharp "chatter" sound and fuel must be atomized from the spray tip. Pressurizing the entire injector with the control valve open allows us to check more areas of the injector for possible leakage.		
2.	Clause no. 3.7.4 Electronic Unit Injector (EUI)	Injector performance parameters- i. Parameters- 16-71 G3B locomotives ii. Locomotive Mode WDG4, WDP4 iii. Plunger dia (inch 0.563 iv. Normal outp (mm3/stroke)- 95 (1100 max.) v. Minimum outp (mm3/stroke)-61 vi. Injection ra (mm3/crank degree)-55 vii. Stroke per minu (typical rate speed)-900 viii. Stroke p minute (minimu rated speed)- 200 ix. Stroke per minu (max. speed)-1020 x. Peak rocker ar load (lbs)- 3500 xi. Plunger strok	Most items noted in this operating parameter list is dependent upon the testing methodology and the unique equipment used for testing, making these exact specifications at best "guidelines".	These data may vary from OEM to OEM depending upon design therefore modified as for guideline purpose only. As engine rpm at rated power is 954.	-	-	Injector performance parameters (These data are for guidelines purpose only)- i. Parameters- 16-710 G3B locomotives ii. Locomotive Model- WDG4, WDP4 iii. Plunger dia (inch)- 0.563 iv. Normal output (mm3/stroke)- 950 (1100 max.) v. Minimum output (mm3/stroke)-61 vi. Injection rate (mm3/crank degree)-55 vii. Stroke per minute (typical rated speed)- 954 viii. Stroke per minute (minimum rated speed)- 200 ix. Stroke per minute (max. speed)-1020 x. Peak rocker arm

		(inch)- 0.75 xii. Injection pressure (psi)-14500-17500 xiii. Peak injection pressure (psi)-18000 xiv. Valve opening pressure(psi)- 3100±300 xv. Valve closing pressure (psi)-2100-2550					load (lbs)- 3500 xi. Plunger stroke (inch)- 0.75 xii. Injection pressure (psi)-14500-17500 xiii. Peak injection pressure (psi)-18000 xiv. Valve opening pressure (psi)- 3100±300 xv. Valve closing pressure (psi)-2100-2550
3.	Clause no. 3.7.4 Electronic Unit Injector (EUI)	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.	This is meaningless information since there are numerous items that influence injector output	There will only one spray tip configuration for this injector, hence marking not required on spray tip.	-	-	Deleted
4.	Clause no. 3.7.4 Electronic Unit Injector (EUI)	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-	This is a little confusing. There is only one spray tip configuration for this injector p/n, therefore why is it necessary to identify? This is an extra step in the manufacturing process and will add cost without adding value. This requirement should be dropped.	There will only one spray tip configuration for this injector, hence marking not required on nozzle tip.	-	-	Deleted

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5.	Clause no. 3.7.5 Engine Control Unit, para-1	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.	This is not clear. The Interstate-McBee ECU has just one CAN interface for diagnostics and monitoring systems. What other control systems would you want to interface?	It is clarified that only one CAN interface is required for diagnostic and monitoring systems.	-	-	Communication with other units is established via a serial interface and CAN bus protocols. Through a CAN interface the system communicates for diagnostics and monitoring purpose.
6.	Clause no. 3.7.5 Engine Control Unit, para-2	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.	Our software does not currently have this capability, but it can be done with both hardware and software modifications to our ECU.	Interstate has agreed to provide this functionality.	-	-	No change

7.	Clause no. 3.7.5 Functional requirements of the ECU	**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.	A little vague, can we get more details from RDSO?	ECU must be able to vary the starting fuel injection quantity for ease in engine starting.	Interstate's ECU does provide a wide fueling window for starting the engine. We also have incorporated a white smoke reduction routine within that starting program based on engine temperature. If I am interpreting your requirement correctly, we do not currently have specific selectable start minimum or start maximum quantities, only selectable window limits.	Interstate does meet the functional requirement desired in this clause. Slight modification is required for more clarity.	Variable start quantity should be provided, by which start quantity is automatically increased during start-up.
8.	Clause no. 3.7.5 Functional requirements of the ECU	**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.	Why is this necessary?	Software of ECU must have the provision for adjustment of rpm or load at any notch, if required. This is required for research purposes on test bed.	Interstate has experience in variable load and speed applications. We have an ECU program for this on marine applications. I am confident that we can develop software specifically for use on your test bed in Lucknow.	Interstate has agreed to provide this.	No change
9.	Clause no. 3.7.5 Functional requirements of the ECU	**Cylinder Equalization by means of Exhaust Gas**	-	This matter has been discussed in detail and it is felt that induction of	-	-	Deleted

		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.		this feature would lead to severe maintenance issues as any faulty reading of any one sensor would affect loco performance.			
10.	Clause no. 3.7.5 Functional requirements of the ECU	**Temperature Dependent Idling Speed and Quantity Limitation:** At low temperature, the engine can be run at some higher idling speed. With	This is a very complex requirement. What is the goal?	This matter has been deliberated in detail and it is proposed to drop this requirement to avoid complication.	-	-	Deleted.

		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.					
11.	Clause no. 3.7.5, Functional requirements of the ECU	**Click Test:** On first commissioning of the engine, the cabling of the solenoid valves can be checked for correctness by a click test.	Intestate McBee does not currently have this test, but it can be added. We have an injector cutout test with the engine running	This is required to ensure that all solenoids are in working condition before starting of engine. Other OEMs provide this functionality.	Just because the solenoid clicks, does not mean that the control valve is working correctly. Injector cutout testing does tell you whether an entire injector is functioning. We can add a click test function to our ECU program.	Interstate has agreed on this.	No change
12.	Clause no. 3.7.7, Sensors	**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	Not currently in our system, but planned for future release.	This is required to detect the position of reference cylinder (firing order) and measure rpm of engine. How does Interstate ECU manage this function?	The Interstate Engine Management System (EMS) uses speed and position sensors mounted over the engine flywheel, not the camshaft. We use the starter ring gear for speed sensing and installed pin in the flywheel for position sensing. We currently are using redundant speed and position sensors only in our	Functional requirement is achieved. Slight modification is required to bring in more clarity.	**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 piston According to this input of the hall sensor, ECU can calculate the start of injection and duration of injection

		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.			marine applications, but they can be adopted for RDSO's requirements as well.		and send the signal to the EUIs. Two speed and cam position hall sensors for each loco will be required for reliability purpose.
13.	Clause no. 7.1 Pre-dispatch inspection	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 bidder's works. 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.	This can be done, but we will need to hire a 3rd party	Matter discussed and it is felt that FMEA is not required at this stage.	-	-	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.
14.	Annexure-1, Engine Performance Data	Fuel pressure- 4.3 bar	Incorrect, pressure will need to be higher	This is the actual figure, recorded on test bed	-	-	Fuel pressure- 6.6 bar (approx.)