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INTERNATIONAL CENTRE FOR AUTOMOTIVE TECHNOLOGY

[A Division of NATRiP Implementation Society (NATIS), Govt. of India]

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Date: 29.03.2017

DEVELOPMENT TEST REPORT

On

Laboratory and On Road Emissions Testing of In-Use Passenger Vehicles in India

For

M/S INTERNATIONAL COUNCIL FOR CLEAN TRANSPORTATION

(1225 Eye Street, NW, Suite 900 Washington, DC 20005 (202) 534-1605)

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Test Site: ICAT, IMT Manesar & Docket No:-47334

Test Date: Oct'2016 to Jan'2017

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1. Executive Summary:

The International Centre for Automotive Technology (ICAT) was contracted by the International Council on Clean Transportation (ICCT) to conduct in-use testing of three light-duty diesel and petrol vehicles, for correlation of Laboratory v/s PEMS.

Three vehicles were procured for this project.

- Hyundai Elite I20 Petrol (Asta Version)
- Hyundai Elite I20 Diesel (Sportz Version)
- Mahindra & Mahindra XUV 500 W6 with Start-Stop feature

All the tests were performed on above three vehicles as per project plan i.e. Chassis Dynamometer tests and On Road test using PEMS. The test results gave insights on the current emissions levels of three, in-use, popular vehicles sold in Indian Market. Also the data showed the gap between Laboratory v/s On Road Emission levels and provide inputs on potential improvements to vehicle technologies and regulations to improve emissions on the road.

2. Background:

The International Council on Clean Transportation (ICCT) is an independent non- profit organization whose mission is to support policymakers around the world in reducing energy consumption and conventional pollutant and greenhouse gas emissions from transportation in order to improve air quality and human health and mitigate climate change.

Serious concerns have been emerged in the last few years over the emission performance of diesel cars in real-world driving conditions. This project is focused towards comparing lab based emissions v/s real world emission measurement. For this, in total 3 cars were tested whose results are presented in the report with detailed analysis. This report mentions specifications of measurement equipments used, the testing methodology, and the conclusion.

While doing real-world emission data collection, vehicles were also driven differently as per EU Real Driving Emissions (RDE) regulatory requirements and actual Indian conditions. It is interesting to note difference in emission levels for each vehicle while being driven as per above two conditions.

3. Scope of Work:

Three in-use Vehicles were procured from the market for executing the project. The project consisted of CO2 and exhaust emission measurements on popular Indian Passenger Vehicles. The project was divided in three tasks as below: -

- Chassis dynamometer testing
- Portable emission measurement system (PEMS) testing
- Analysis and report

Under Chassis Dynamometer testing, all the 3 vehicles were required to be tested on MIDC and WLTC cycles in cold and hot start conditions respectively. Repeatability of the results had to be ensured by collecting 2 samples for each test configuration. This activity required second by second measurement of CO, HC, NOx, PM, PN, CO2, along with final bag results. EGR signal was to be recorded for diesel vehicles.

Under PEMS testing, all the 3 vehicles were required to be tested on Outside Road as per European legislation and Indian conditions respectively to capture Real Driving Emissions. This activity required second by second measurements of CO, NOx, CO2, Fuel flow; along with total results via EMORAD post-processing tool. EGR signal was to be recorded for diesel vehicles.

Data Analysis and report preparation would conclude the project.

4. Test Vehicles:

Vehicles had to be procured from secondary market (in-use) as per below conditions: -

- Vehicle age should be less than 3 years.
- Vehicle in proper operational condition with proper service/maintenance records.
- The final vehicles selected should be no older than three years of age, in proper operational condition, and have been operated between 5,000 and 16,000 km per year.

Three vehicles were procured for this project as below: -

- Hyundai Elite I20 Petrol (Asta Version)
- Hyundai Elite I20 Diesel (Sportz Version)
- Mahindra & Mahindra XUV 500 W6 with Start-Stop feature

I20 Petrol **I20 Diesel** **XUV 500**

Figure 1: Vehicles procured

Specification of the vehicles was as below: -

Table 1: Vehicles specifications

Parameters	**Vehicles**		
	I20 Petrol	**I20 Diesel**	**XUV 500**
Registration Date	27-May-2015	09-Nov-2015	06-May-2015
Odometer Reading	16412 kms	12157 kms	13328 kms
Previous Owner	1^{st} (Personal use)	1^{st} (Personal use)	1^{st} (Personal use)
Any Accidental History	No	No	No
Fuel	Petrol	Diesel	Diesel
Engine Size,cc	1197	1396	2179
Major Technology	VVT	Common Rail, EGR, Non-DPF	Common Rail, EGR, Non-DPF, Start-Stop

Torque(kg.m)	11.7@4000	22.4@1500-2750	33.0@1600-2800
Power (kw)	62	55.2	103
TA FE(kmpl)/CO2(gm/km)	18.6 /127.1	21.9 / 122.4	15.2 / 176.4
Emission Compliance	BS IV M1 Class	BS IV M1 Class	BS IV M3 Class
Vehicle Weight	1080	1161	1860

All three vehicles were thoroughly checked for any possible engine or after-treatment malfunction diagnostic trouble codes (DTC) using an Engine Control Unit (ECU) scanning tool before starting test activities. All the vehicles were found in good mechanical condition and none of them showed any OBD fault code or other anomalies.

The Diesel and Petrol fuel used for this project was from commercially available supply in India. Fuel used for all three test vehicles were collected from the single batch during entire project

Please note that XUV 500's Start-Stop feature was always kept Activated during both Chassis as well as PEMS testing.

5. Project Activities:

The project was divided in 3 Tasks as below: -

- Task1: Chassis dynamometer testing
- Task2: Portable emission measurement system (PEMS) testing
- Task3: Analysis and report

5.1 Task 1: Chassis Dynamometer Testing

Following activities were planned under Task 1: -
- To run standard emission cycles and measure the fuel consumption data and legislative regulated emission species (NOx, HC & CO) on three vehicles on chassis dynamometer test.
- PM & PN (particulate number) were to be measured for diesel vehicles only.
- Emission tests to be done on 4X4 chassis dyno for both petrol and diesel vehicles.

Task 1 required vehicle emission testing over two different regulatory test cycles viz. Modified Indian Driving Cycle (MIDC) and Worldwide Harmonized Light Vehicle Test Cycle (WLTC). For each regulatory cycle, two sets of cold start and hot start emission test had to be performed. Cold test was started after the overnight soaking and hot test was started immediately after 30 minutes of end of cold test. Total number of emissions tests planned under Task1 is given as below:

Table 2: Tests under Task 1

Vehicle	MIDC		WLTC		Total
	Cold	Hot	Cold	Hot	
I20 Petrol	2	2	2	2	8
I20 Diesel	2	2	2	2	8
XUV 500	2	2	2	2	8
					24

5.1.1 Task 1 - Deliverables:

Second by second data and total bag results data to be captured during all emissions tests for following pollutants. Fuel Consumption based on carbon balance method also to recorded. EGR data was also to be captured for diesel vehicles.

Table 3: List of deliverables

Emissions	Diesel	Petrol
HC		✓
NOx	✓	✓
HC+NOx	✓	**N/A**
CO	✓	✓
CO_2	✓	✓
PM	✓	**N/A**
PN	✓	**N/A**

N/A: Not Applicable

5.1.2 Task 1 - Test Setup and Methodology:

Emission tests over two regulatory cycles had to be run on Chassis dynamometer. Test conditions used for consistency are defined as below:-

Table 4: Test conditions

Test conditions	Test values
Ambient air température (deg C)	23±2
Absolute Humidity	5.5 to 12.2 g H2O/kg dry air
Chassis Dyno drive mode	4x4
Vehicle soak time for Cold test	Overnight soaking
Time between End of Cold test and Start of hot test	30 minutes

Layout and Technical Specification of Chassis Dynamometer and Analyzer set used are depicted here.

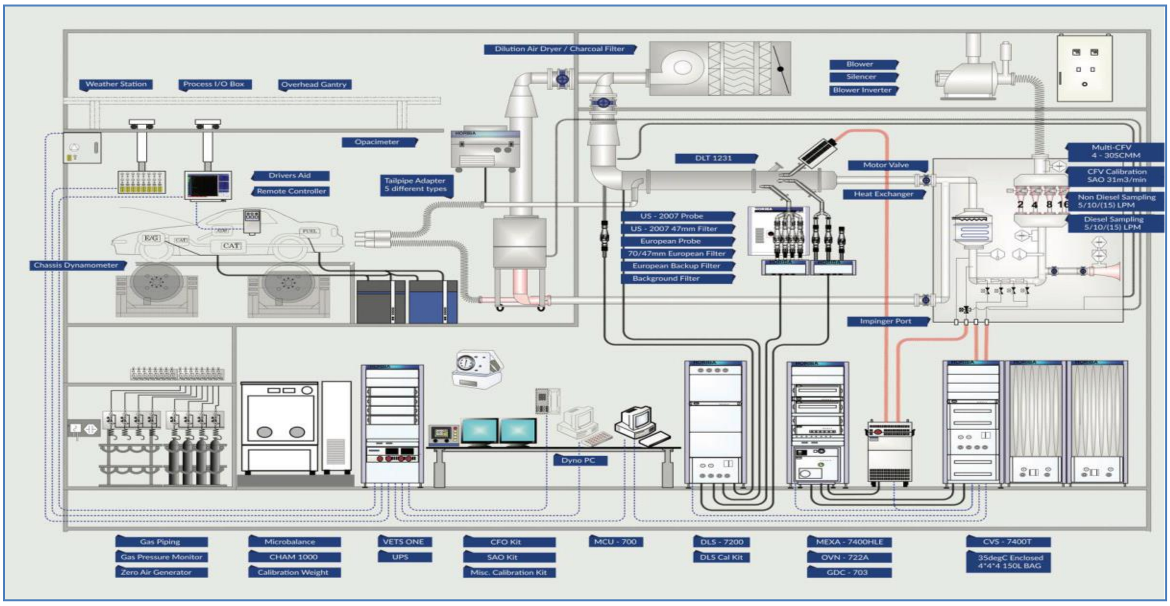


Figure 2: Chassis Dynamometer and Analyzer Layout

Table 5: Chassis dynamometer Lab specifications

Test Equipment	**Make-Model**	**Specifications**
Dynamometer	AVL Emission Test Systems, GMBH 1219.2 mm AC machine Chassis Dyno	Base inertia per axle :approx 1300Kg
		Inertia range per axle: approx. 454 Kg (1000 lbs) – 5,400 Kg (12,000 lbs)
		Maximum speed: 250 Km/h
		Maximum axle load: approx. 4,500 Kg
Constant Volume Sampler (CVS)	HORIBA Emission Test Systems, CVS 7400T	Availability of four critical flow venturis (CFV) of 2,4,8 and 12 m3/min, up to 13 different flow rates shall be automatically selectable with a maximum flow rate of 30 m3/min
PN Counter	AVL	All standard Interfaces like TCP/IP, RS 232 and CAN Bus (all with AK-Protocol) as well as Digital/Analog-IO are available to ensure an easy integration into different automation systems
PM	HORIBA	DLS-7100 particulate sampling system controls and monitors the sample through the particulate filters, PM filter media 47mm and 70mm filter assemblies, 70mm filter supplied with a backup filter.

The test cycles were configured in Driver's Aid software of Chassis Dynamometer Lab. Details of the cycles are given here.

<u>MIDC</u>

MIDC is Modified Indian Drive Cycle which is used as a standard cycle in India for Type-1 test of BSIV 4 wheeled vehicles as per TAP document. Maximum vehicle speed in MIDC is limited to 90 kmph.

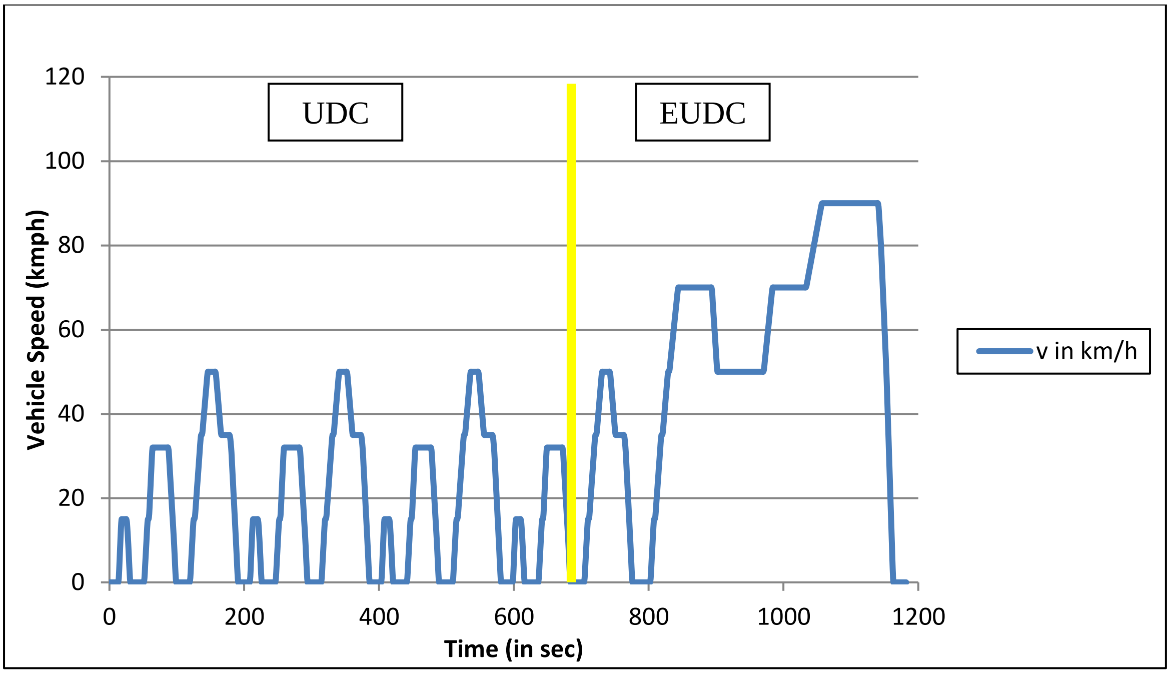


Figure 3: MIDC Test Cycle

<u>WLTC</u>

WLTC is Worldwide Harmonized Light Vehicle Test Cycle that has been developed by the UN ECE GRPE (Working Party on Pollution and Energy) group and is defined under Worldwide harmonized Light vehicles Test Procedure (WLTP) ECE/TRANS/WP.29/2016/68e.

There are 3 classes of WLTC test cycles depending on power-to-mass ratio (PMR parameter is defined as the ratio of "Rated Power in W / Curb mass in Kg") and the maximum vehicle speed (v_max) as declared by the manufacturer. All the three 3 test vehicles viz. I20_P, I20_D & XUV500 fall under Class 3 category Please refer below for more details: -

Category	PMR, W/kg	Speed Phases	Comments
Class 3	PMR > 34	Low, Middle, High, Extra-High	If v_max < 135 km/h, phase 'extra-high' is replaced by a repetition of phase 'low'.
Class 2	34 ≥ PMR > 22	Low, Middle, High	If v_max < 90 km/h, phase 'high' is replaced by a repetition of phase 'low'.
Class 1	PMR ≤ 22	Low, Middle	If v_max ≥ 70 km/h, phase 'low' is repeated after phase 'middle'. If v_max < 70 km/h, phase 'middle' is replaced by a repetition of phase 'low'.

Figure 4: WLTC test cycle classes

Under Class 3, there are 4 speed phases viz. Low, Middle, High and Extra-High. However, the extra high speed phase was excluded from chassis testing emission measurement. It was only used to determine the Real Driving Emissions characteristic curve CO2 values (g/km) for motorway phase.

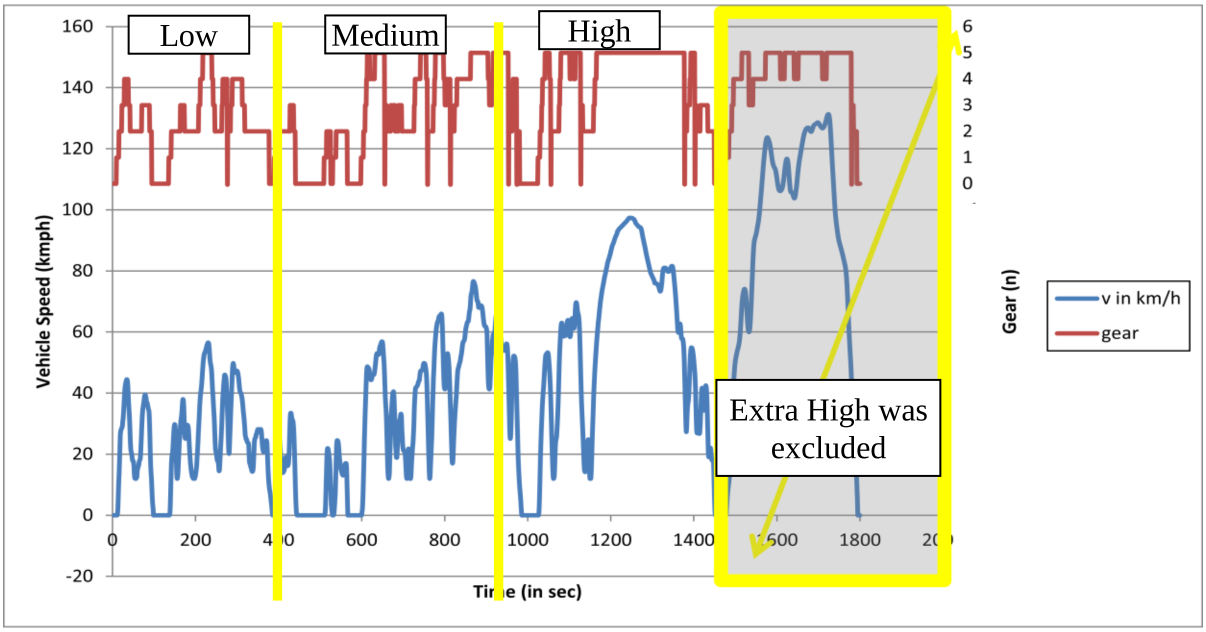


Figure 5: WLTC Test cycle

Road Load Equation values

Road Load Equation values of all 3 vehicles, to be used for both MIDC and WLTC were calculated as per WLTP procedure ECE/TRANS/WP.29/2016/68e. Details are given in below table.

Table 6: Coast down values

Parameters	Elite i20 P	Elite i20 D	XUV 500 W6
V max (kmph)	154	165	180
Tire (drr in m)	0.298	0.298	0.358
	185/ 70 R14	185/ 70 R14	235/65 R17
Eng Power (PS)	83@6000	90@4000	140@3750
Eng Power(W)	61046.5	66195	102970
Unlaiden wt (kg)	1080	1161	1860
GVW	1515	1630	2450
Power/Wt ratio	56.5	57.0	55.4
WLTC Class	3b	3b	3b
Mass in running order	1155	1236	1971
Actual Mass	1155	1236	1971
Maximum Veh Load	335	369	454
Mass representative of vehicle load	50.25	55.35	68.1
Test mass of the vehicle	1230.25	1316.35	2064.1
Type Approval F.E. (kmpl)	18.6	21.9	15.2
CO2	127.1	122.4	176.4
Torque (kg.m)	11.7@4000	22.4@ 1500-2750	33.0 @ 1600-2800
Width (mm)	1734	1734	1890
Height (mm)	1505	1505	1785
Gears	5	6	6
f0	**172.235**	**184.289**	**288.974**
f1	**0**	**0**	**0**
f2	**0.0478**	**0.0481**	**0.0631**

Gear shift points in WLTC

Gear shift points during WLTC were calculated differently for each vehicle as per WLTP procedure ECE/TRANS/WP.29/2016/68e. For this purpose, Heinz Steven tool ver. 02.06.2016 was used to input all relevant data and output gear shift points.

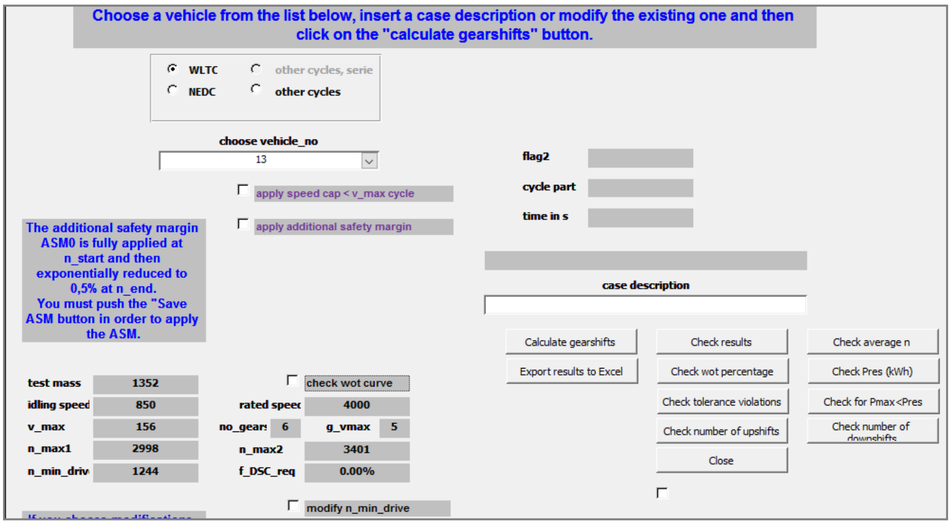


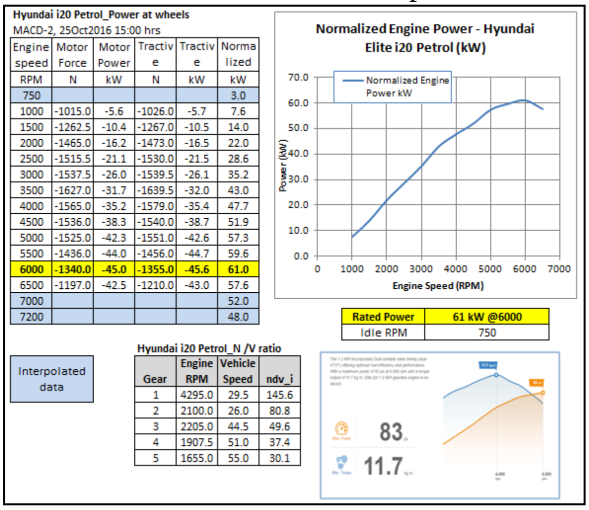
Figure 6: Gear shift points in WLTC

In order to use Heinz Steven tool for calculating Gear Shift points for each vehicle during WLTC cycle, following tests were done on MACD: -

1. Power at wheels to derive Engine WOT (Wide Open Throttle) curve in Nm.

2. Ndv ratio – Engine Speed (N) / Vehicle Speed (kmph) ratio.

The result of the MACD trials is presented below for all 3 vehicles: -



Hyundai i20 Petrol_Power at wheels

MACD-2, 25Oct2016 15:00 hrs

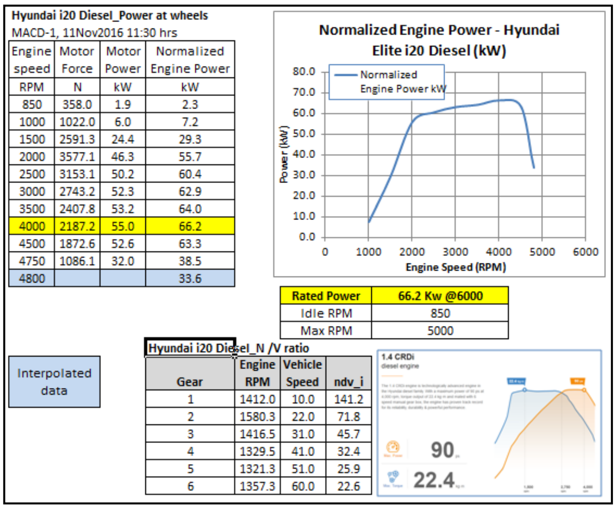
Engine speed	Motor Force	Motor Power	Tractive	Tractive	Normalized
RPM	N	kW	N	kW	kW
750					3.0
1000	-1015.0	-5.6	-1026.0	-5.7	7.6
1500	-1262.5	-10.4	-1267.0	-10.5	14.0
2000	-1465.0	-16.2	-1473.0	-16.5	22.0
2500	-1515.5	-21.1	-1530.0	-21.5	28.6
3000	-1537.5	-26.0	-1539.5	-26.1	35.2
3500	-1627.0	-31.7	-1639.5	-32.0	43.0
4000	-1565.0	-35.2	-1579.0	-35.4	47.7
4500	-1536.0	-38.3	-1540.0	-38.7	51.9
5000	-1525.0	-42.3	-1551.0	-42.6	57.3
5500	-1436.0	-44.0	-1456.0	-44.7	59.6
6000	-1340.0	-45.0	-1355.0	-45.6	61.0
6500	-1197.0	-42.5	-1210.0	-43.0	57.6
7000					52.0
7200					48.0

Rated Power	61 kW @6000
Idle RPM	750

Hyundai i20 Petrol_N /V ratio

Gear	Engine RPM	Vehicle Speed	ndv_i
1	4295.0	29.5	145.6
2	2100.0	26.0	80.8
3	2205.0	44.5	49.6
4	1907.5	51.0	37.4
5	1655.0	55.0	30.1

Figure 7: MACD result of I20_P



Hyundai i20 Diesel_Power at wheels

MACD-1, 11Nov2016 11:30 hrs

Engine speed	Motor Force	Motor Power	Normalized Engine Power
RPM	N	kW	kW
850	358.0	1.9	2.3
1000	1022.0	6.0	7.2
1500	2591.3	24.4	29.3
2000	3577.1	46.3	55.7
2500	3153.1	50.2	60.4
3000	2743.2	52.3	62.9
3500	2407.8	53.2	64.0
4000	2187.2	55.0	66.2
4500	1872.6	52.6	63.3
4750	1086.1	32.0	38.5
4800			33.6

Rated Power	66.2 Kw @6000
Idle RPM	850
Max RPM	5000

Hyundai i20 Diesel_N /V ratio

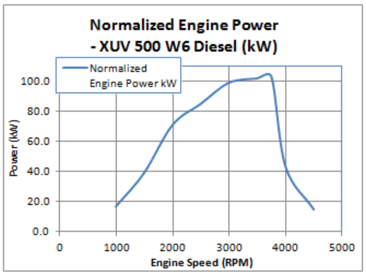
Gear	Engine RPM	Vehicle Speed	ndv_i
1	1412.0	10.0	141.2
2	1580.3	22.0	71.8
3	1416.5	31.0	45.7
4	1329.5	41.0	32.4
5	1321.3	51.0	25.9
6	1357.3	60.0	22.6

Figure 8: MACD result of I20_D

XUV500 W6 Diesel_Power at wheels

MACD-1, 25Nov2016 15:00 hrs

Engine speed	Motor Force	Motor Power	Normalized
RPM	N	kW	kW
1000	1588.6	14.5	16.9
1500	2336.1	33.7	39.2
2000	3142.3	60.9	70.9
2500	3062.5	73.0	85.0
3000	3067.8	85.0	98.9
3500	2650.0	87.5	101.9
3750	2441.1	88.5	103
4000	962.3	37.2	43.4
4500			15.0



Rated Power	103 Kw @3750
Idle RPM	800
Max RPM	4700

Interpolated data

XUV500 W6_N /V ratio

Gear	Engine RPM	Vehicle Speed	ndv_i
1	2141.9	16.3	131.7
2	2213.2	33.6	66.0
3	2054.2	53.9	38.1
4	1989.9	68.5	29.1
5	1754.2	72.4	24.2
6	1755.0	85.5	20.5

Figure 9: MACD result of XUV 500

<u>EGR Capturing Methodology:</u>

I20 Petrol: This vehicle being BS IV petrol vehicle didn’t have EGR so there was no provision for tapping the signal

I20 Diesel: This vehicle had a solenoid valve for EGR operation whose signal was controlled from ECU. It didn’t have any feedback mechanism. Solenoid valve had three wire connector; one out of which was reference voltage (battery voltage), other reference ground & third one had solenoid actuator signal from the ECU.

Ratio of actuator signal voltage and reference signal voltage in percentage was considered as Actual EGR duty. This signal got correlated well with Commanded EGR signal received from the OBD port.

Picture of set-up is as below:

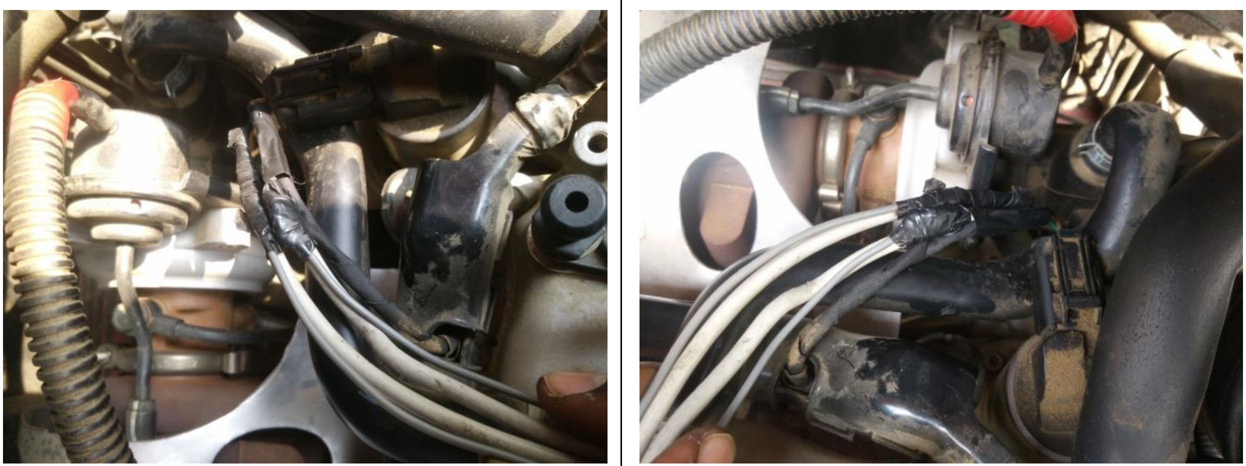


Figure 10: EGR tapping pictures of I20_D

XUV500: XUV 500 vehicle has vacuum controlled EGR. Vacuum hose going to EGR valve was tapped and vacuum going to EGR was measured with a pressure transducer of range -1 to +1 barg. Surface temperature after EGR valve was also recorded during laboratory testing.
Picture of set-up is as below:

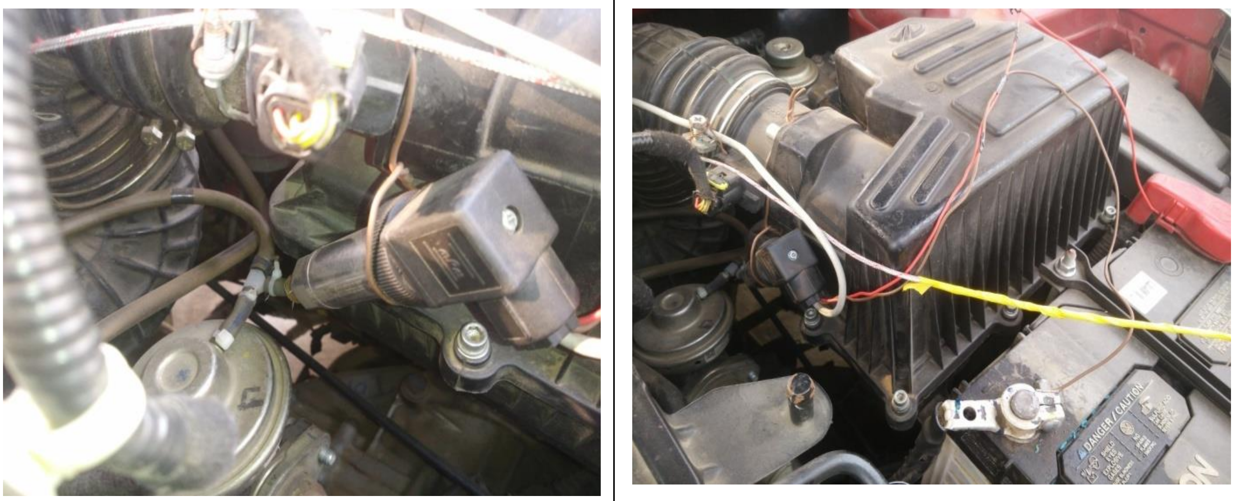


Figure 11: EGR tapping pictures of XUV 500

5.1.3 Task1 - Results:

EGR data analysis:

EGR data was captured on both the vehicles during Task1 Emission tests.

In case of I20_D, the EGR duty was captured in range of 0 to 100%. The EGR behavior was found to be satisfactory in all the MIDC and WLTC tests. However, there are 3 observations as below: -

- Relatively EGR works more in case cold start than in case of hot start.
- Between MIDC and WLTC, WLTC has lesser EGR average opening rate relatively.
- The outcomes can be correlated to NOx results also.

The comparison of average EGR opening rate in I20_D is presented below.

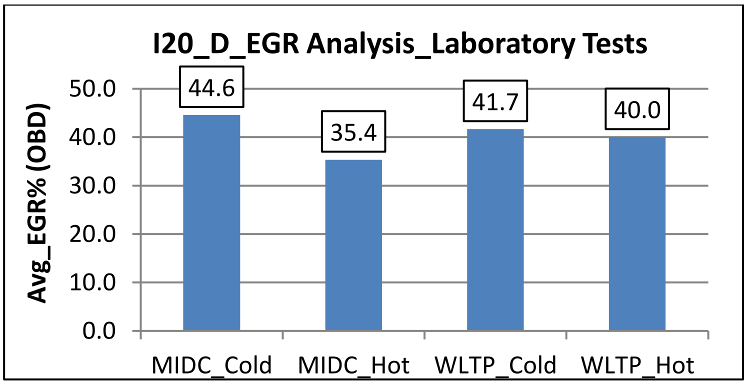


Figure 12: I20_D_EGR Analysis_Laboratory Tests

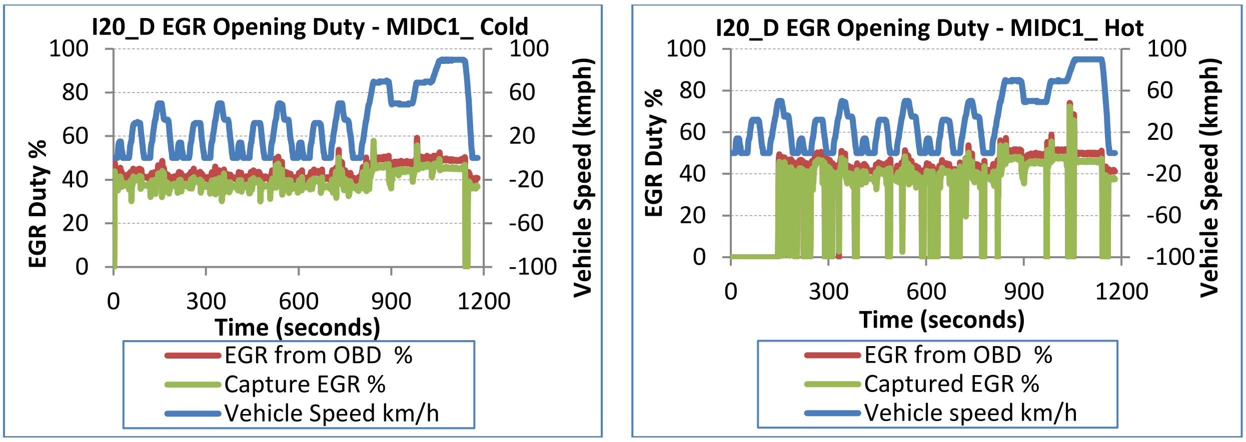


Figure 13: Comparison of EGR Opening Duty in I20_D b/w MIDC1 Cold and Hot

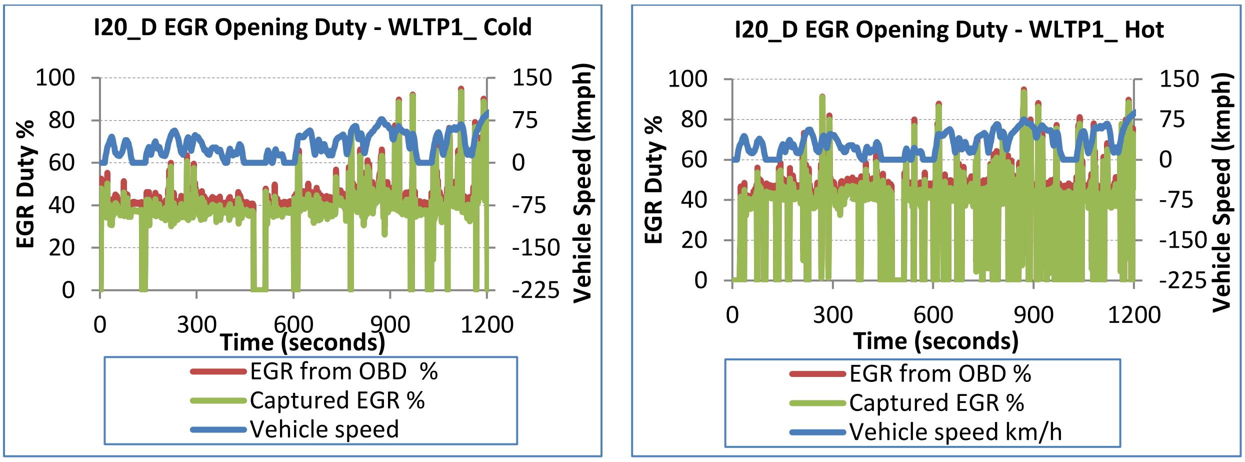


Figure 14: Comparison of EGR Opening Duty in I20_D b/w WLTC1 Cold and Hot

In case of XUV500, the EGR behavior was found almost similar in Cold and Hot conditions. However, EGR worked more frequently in WLTC as compared to MIDC. The comparison of average EGR opening vacuum in XUV500 is presented below.

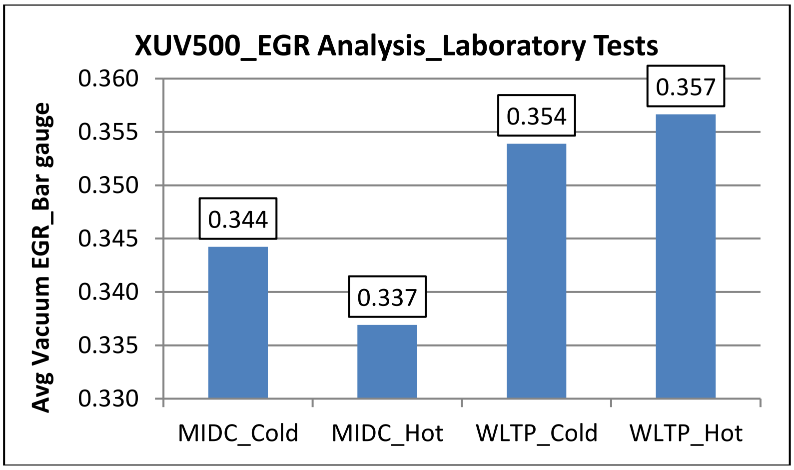


Figure 15: XUV500_EGR Analysis_Laboratory Tests

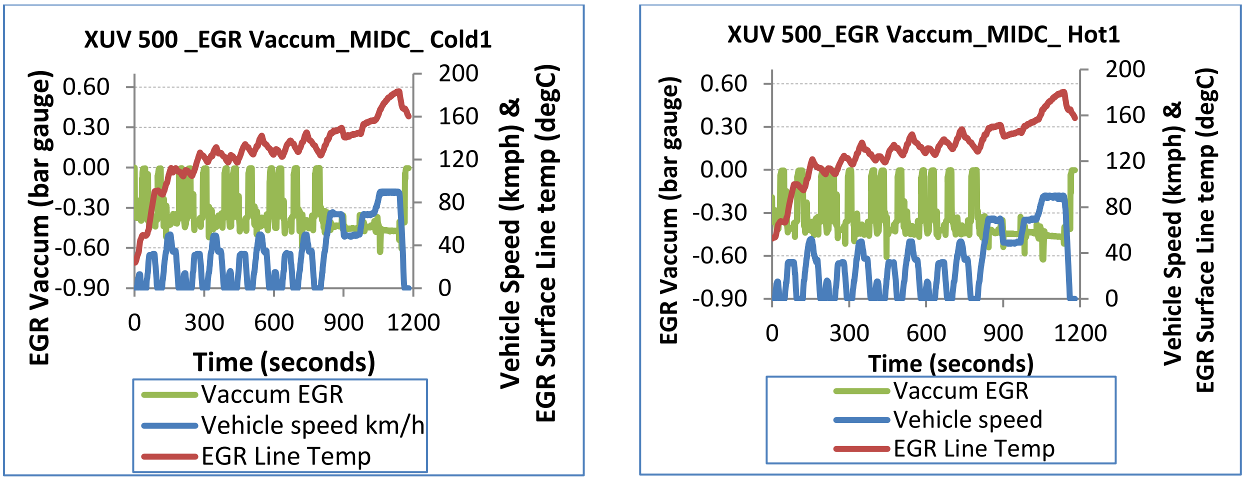


Figure 16: Comparison of EGR Opening Duty in XUV500 b/w MIDC1 Cold and Hot

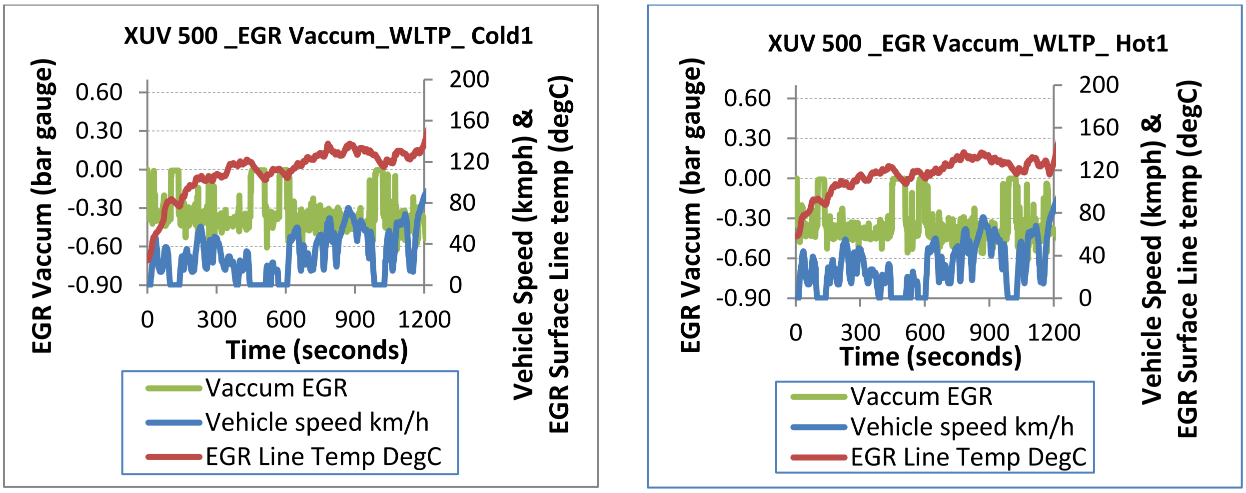


Figure 17: Comparison of EGR Opening Duty in XUV500 b/w WLTC1 Cold and Hot

<u>Emission Results:</u>

I20 Petrol – Modal Traces:

Second by second modal data was logged successfully for I20_P. The data shows that CO and THC were high only in first 3-4 minutes of cold start. Afterwards the emission was very low probably due to catalytic convertor's light-off. The detailed Modal Traces behavior of I20_P is presented below.

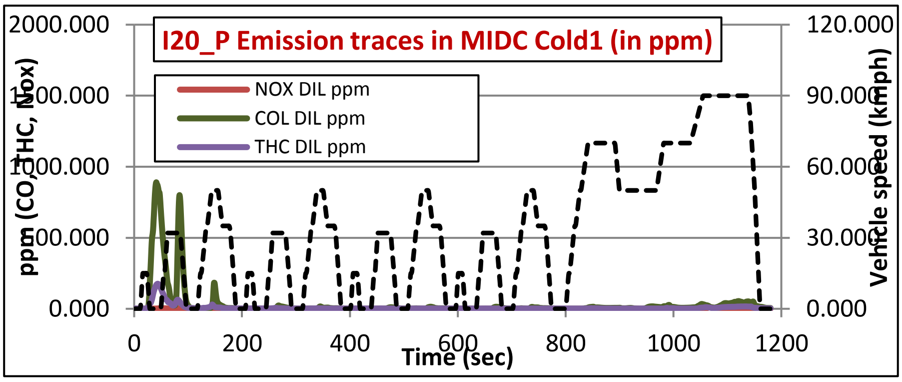


Figure 18: I20_P Emission traces in MIDC Cold 1

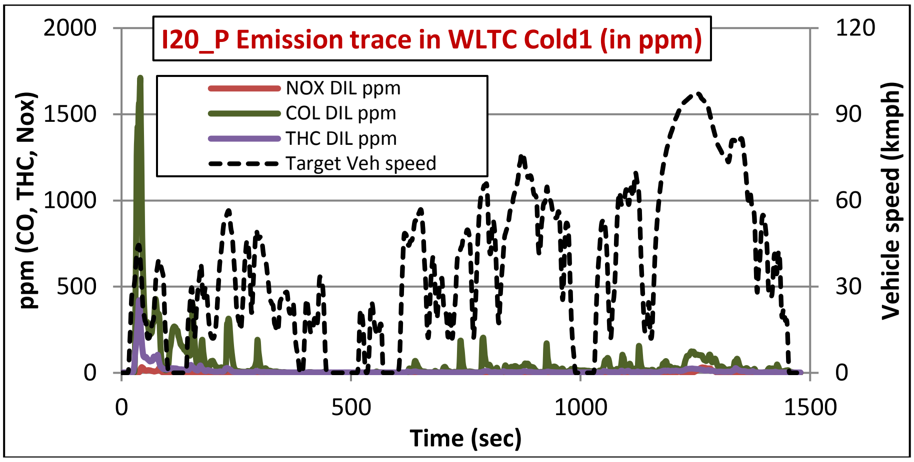
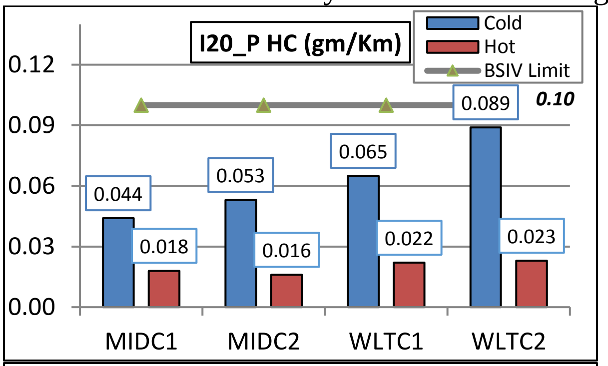
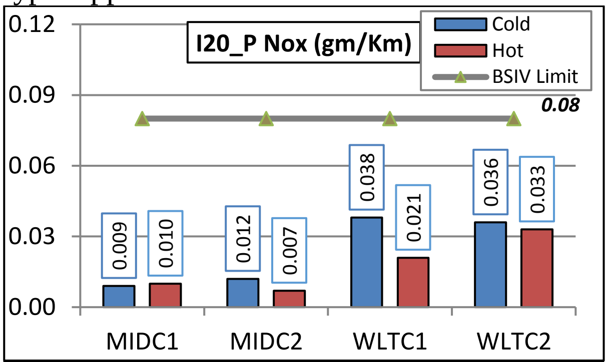


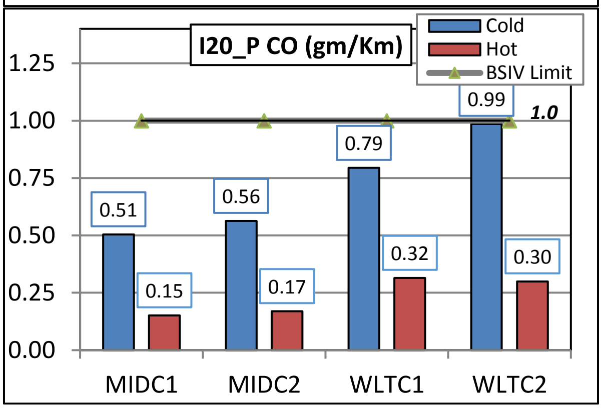
Figure 19: I20_P Emission traces in WLTC Cold 1

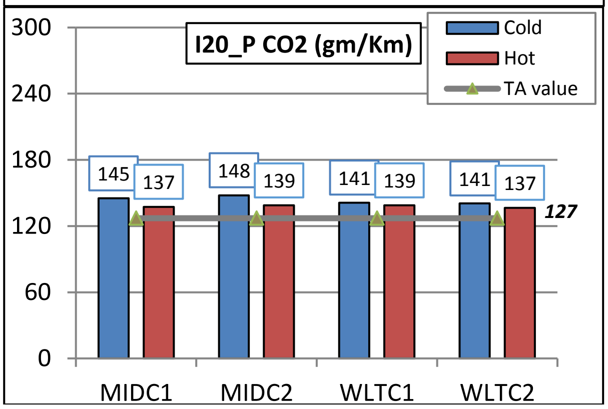
I20 Petrol – Bag Results:

Vehicle passed within BSIV M1 category limits and Fuel Economy value came 1 to 2 kmpl lesser than what was declared by manufacturer during Type Approval.









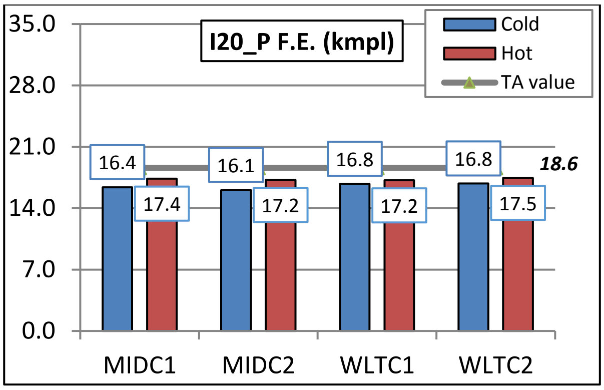


Figure 20: I20_P Bag Results

I20 Diesel – Modal Traces:

Second by second modal data was logged successfully for I20_D. The data shows that NOx traces are relatively higher in WLTC as compared to MIDC, probably due to more aggressive accelerations. The detailed Modal Traces behavior of I20_D is presented below.

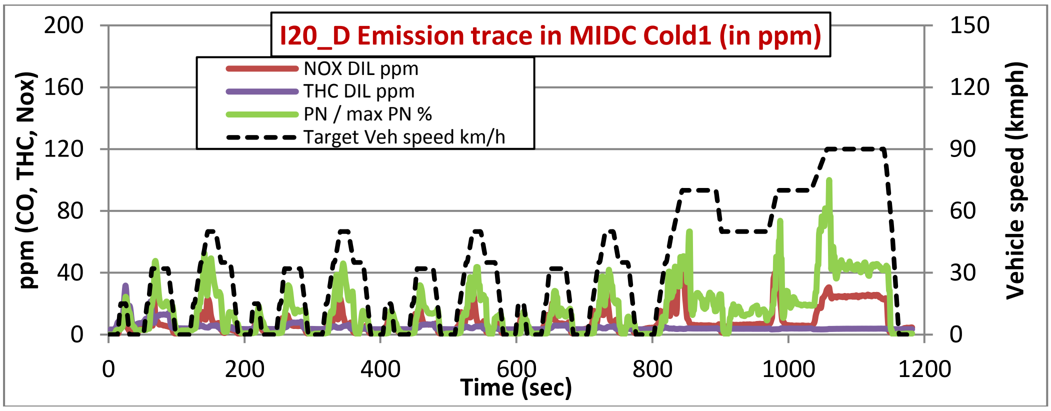


Figure 21: I20_D Emission traces in MIDC Cold 1

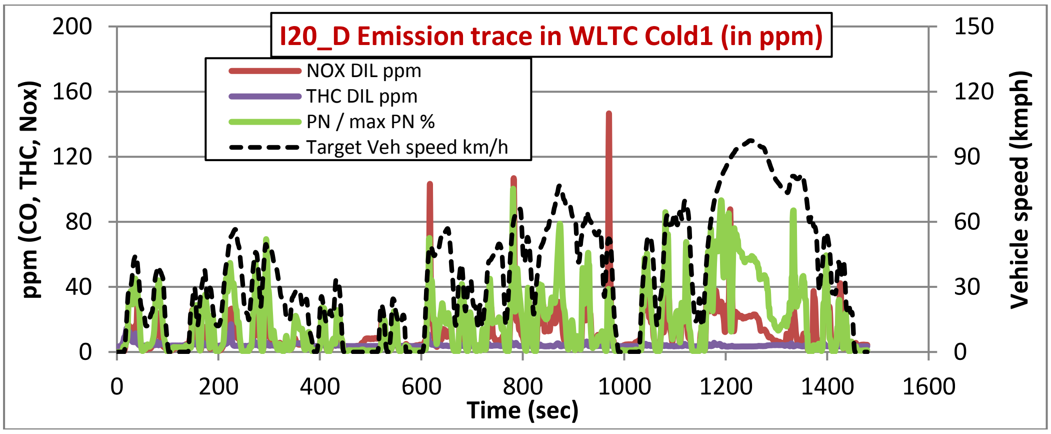


Figure 22: I20_D Emission traces in WLTC Cold 1

I20 Diesel – Bag Results:

Below plot shows comparison between engine operating points during WLTC and MIDC. The WLTC has wider range of both engine load and engine speed.

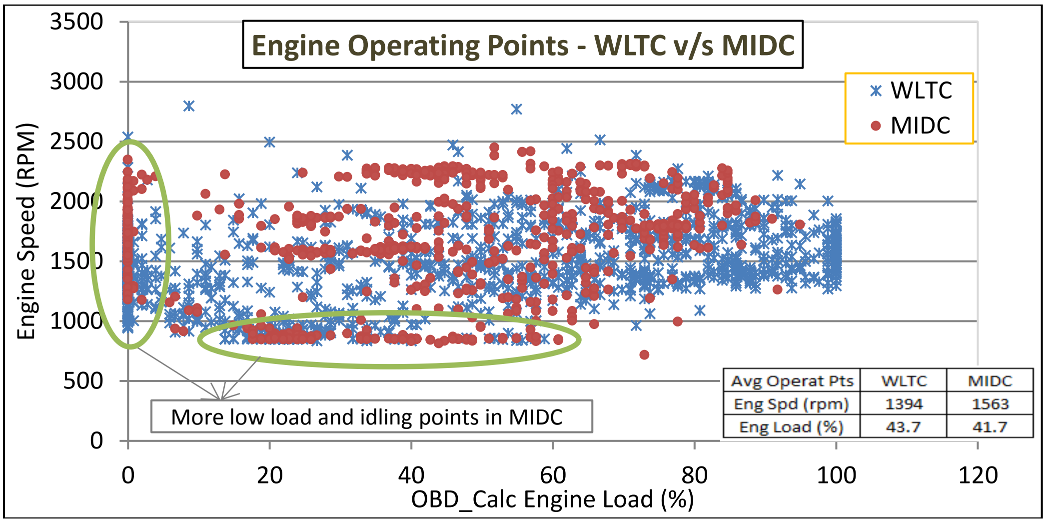
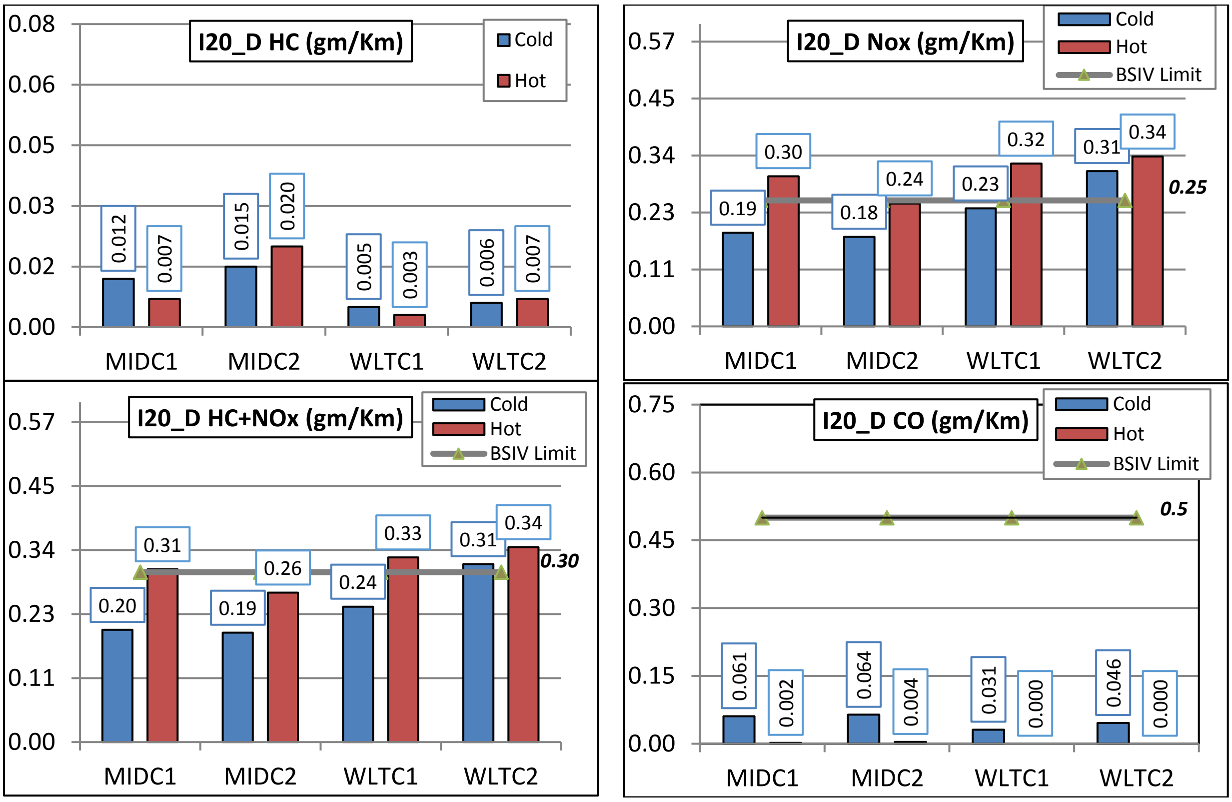


Figure 23: I20_D Engine operating points – WLTC v/s MIDC

I20 Diesel vehicle passed within BSIV M1 category limits and Fuel Economy value also came 1.5 to 2.5 kmpl lesser than what was declared by manufacturer during Type Approval. The detailed plots are given below: -



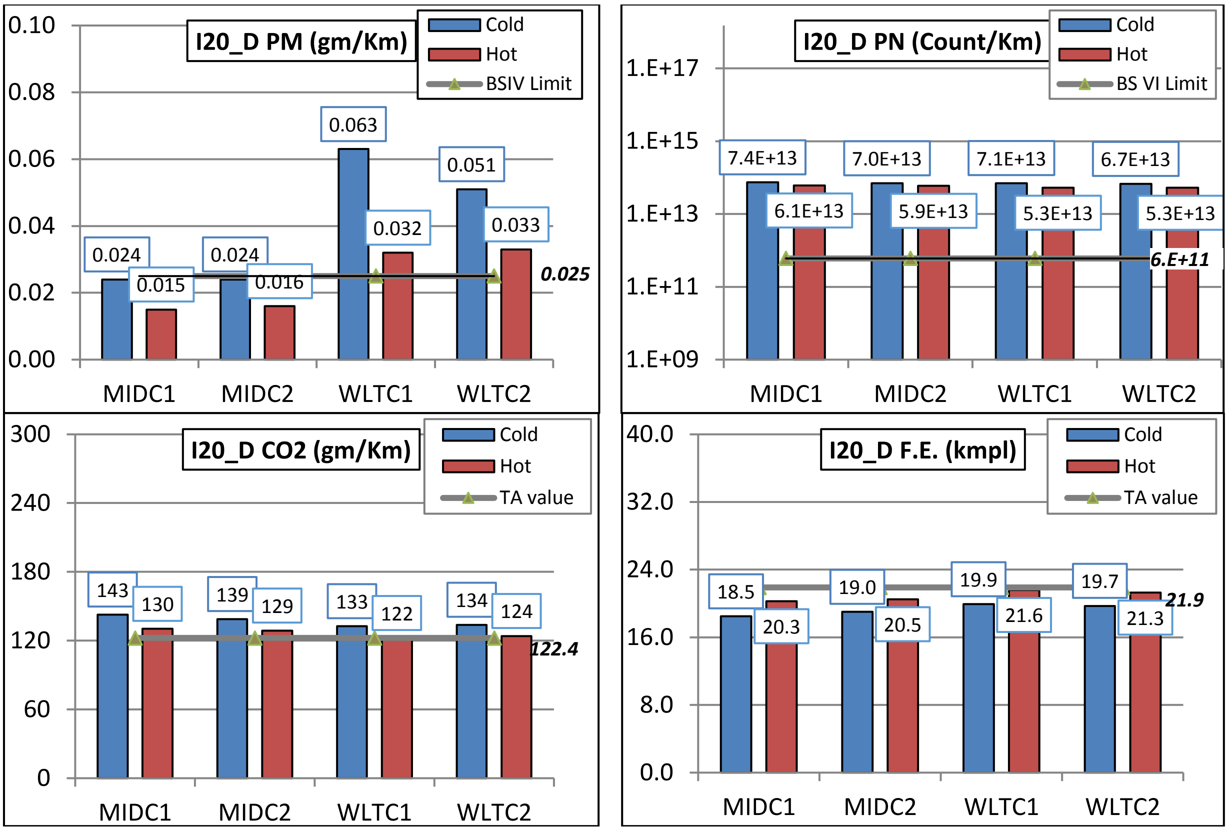


Figure 24: I20_D Bag Results

XUV500 – Modal Traces:

Second by second modal data was logged successfully for XUV 500. The data shows that NOx trace is relatively higher in WLTC as compared to MIDC, probably due to more aggressive accelerations in WLTC cycle. The detailed Modal Traces behavior of XUV 500 is presented below.

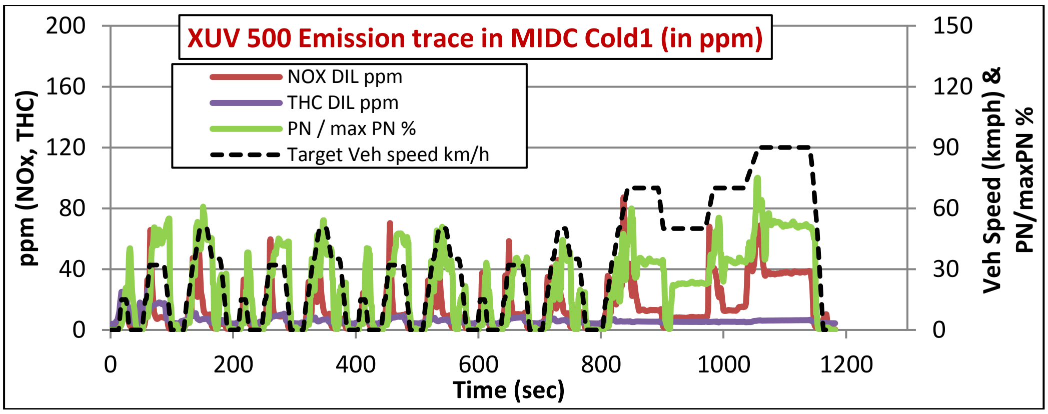


Figure 25: XUV 500 Emission traces in MIDC Cold1

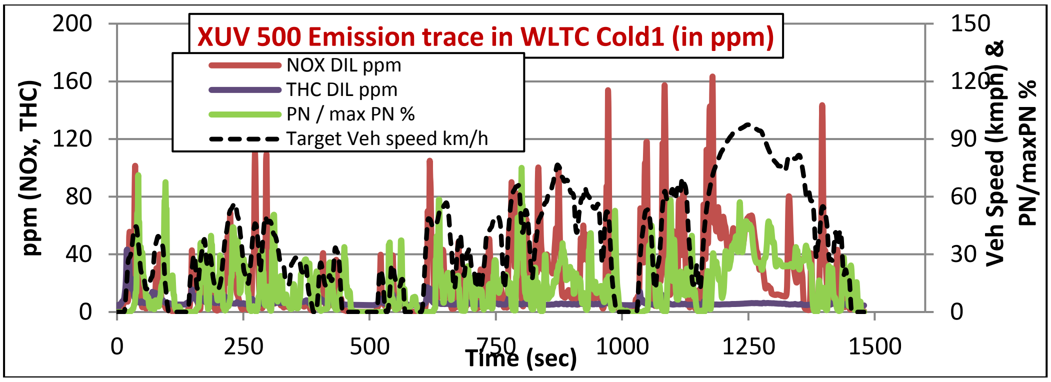


Figure 26: XUV 500 Emission traces in WLTC Cold1

XUV 500 – Bag Results:

Below plot shows comparison between engine operating points during WLTC and MIDC.

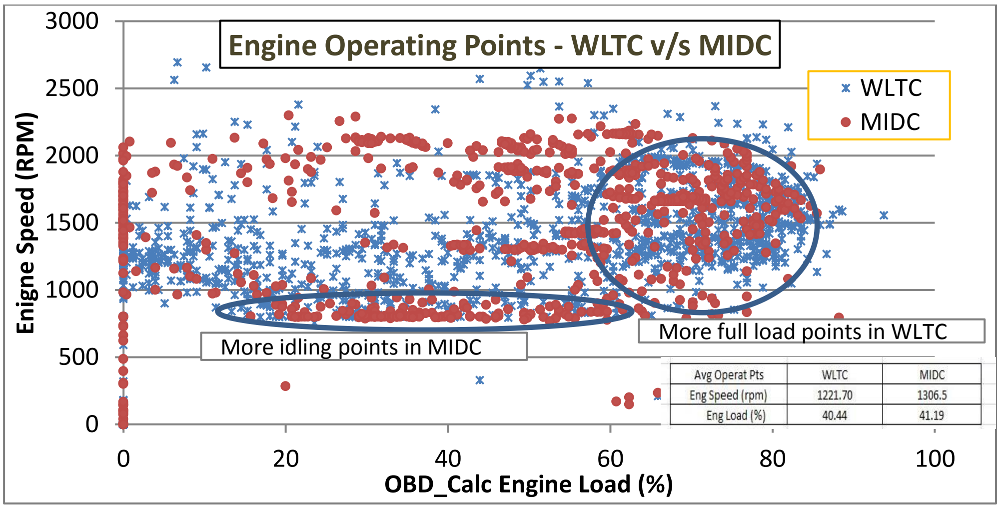
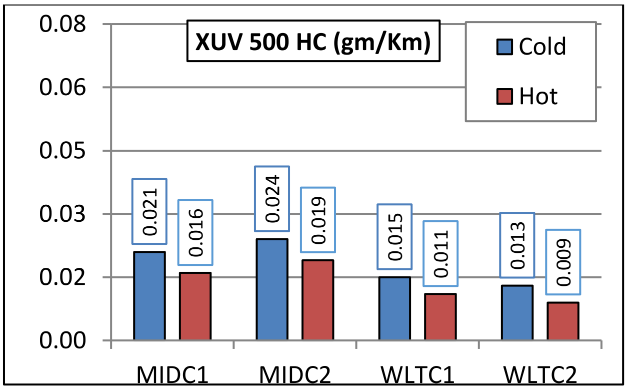
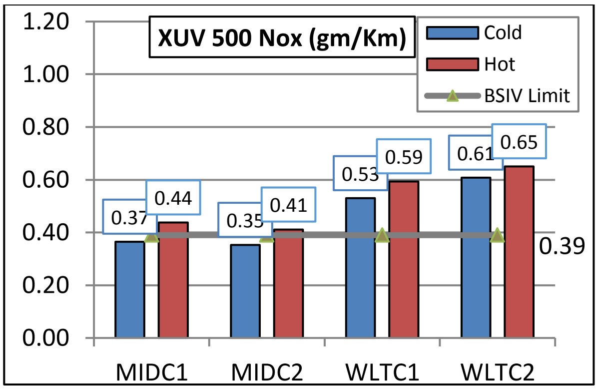


Figure 27: XUV 500 Engine operating points – WLTC v/s MIDC

XUV 500 vehicle passed within BSIV M3 category limits and Fuel Economy value came 0.5 to 2.0 kmpl lesser than what was declared by manufacturer during Type Approval. Please see the figures below.





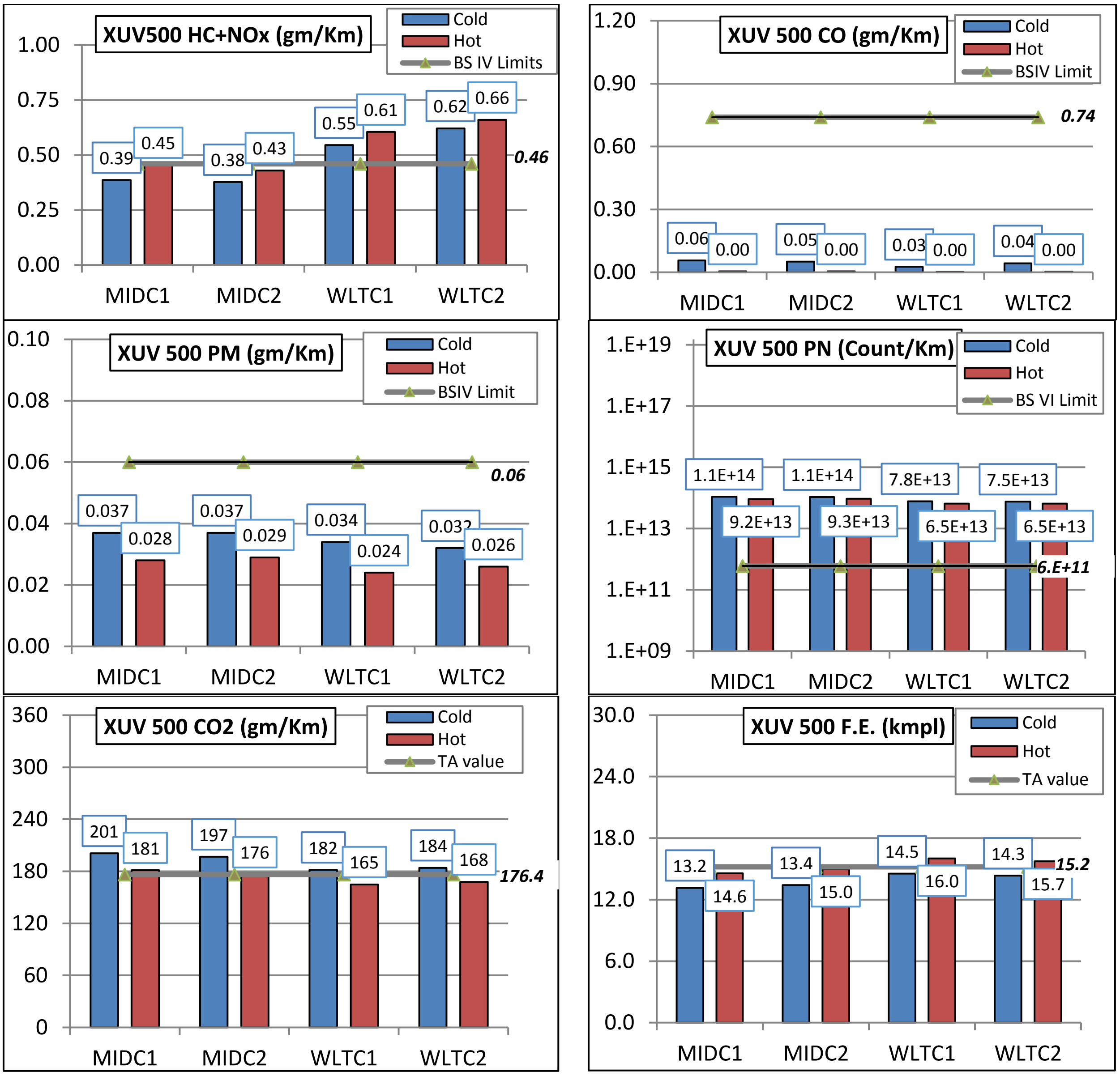


Figure 28: XUV 500 Bag Results

5.1.4 Task1 - Conclusions:

Emission Compliance w.r.t. BSIV regulatory limits

- Firstly, all the three vehicles passed under BSIV cold start MIDC regulatory emissions norms.
- In case of I20_P Cold MIDC testing, CO and HC passed with around 50% margin and NOx passed with 87% margin. It can be concluded that this vehicle's emission levels are comfortably lower than allowed limits.
- In case of I20_D Cold MIDC testing, CO passed 87% margin, NOx passed with 27% margin and HC+NOx passed with 35% margin. However PM passed with margin of just 4%. It can be concluded that this vehicle's emission levels are just meeting the allowed limits.

- In case of XUV500 Cold MIDC testing, CO passed with 93% margin and PM passed with 38% margin. However NOx passed with just 8% margin and HC+NOx passed with 17% margin. It can be concluded that this vehicle's emissions are just meeting the allowed limits.

- To summarize, Petrol Vehicle passes with healthy margin of minimum 50% whereas Diesel Vehicles have less than 10% margin either in NOx or PM.

Comparison of WLTC cold emissions over MIDC cold emissions

- When tested for WLTC, I20_P's CO and HC emissions increased by 60 to 65% while NOx increased by factor of 3.5. This increase in emissions over MIDC may be attributed to relatively more aggressive accelerations and hence more fluctuations in stoichiometric ratio. However, WLTC emission results are still within BSIV limits.

- In case of I20_D, CO and HC emissions reduced by factor of 0.4 to 0.6 while NOx and PM increased by factor of 1.5 and 2.4 respectively. To be noted here, WLTC's PM results surpassed BSIV limits by margin of 128%.

- In case of XUV500, CO and HC emissions reduced by factor of 0.6 while NOx increased by factor of 1.6. Surprisingly, PM reduced by 11% as compared to MIDC. To be noted here, WLTC's NOx results surpassed BSIV limits by margin of 46%.

- To summarize, WLTC emissions are higher than MIDC emissions for both Petrol and Diesel vehicles.

Delta change in Hot emissions over Cold emissions

- In case of I20_P, CO and HC emissions reduced by 68% and NOx reduced by 23%. The reason behind reduced emissions in hot start test may be attributed to faster light-off of catalyst.

- In case of I20_D, CO and HC emissions reduced to almost NIL whereas NOx increased by 35% and PM reduced by 39%.

- In case of XUV500, CO and HC emissions reduced to almost NIL whereas NOx increased by 14% and PM reduced by 24%.

- Overall, emissions reduce by big percentage in Hot emissions as compared to Cold emissions in Petrol vehicles. In case of Diesel vehicles, NOx has increased and PM has reduced by considerable percentage.

Particulate Number in Diesel Vehicles

- Since both the diesel vehicles are Non-DPF BSIV vehicles, the Particulate Number (PN) has been recorded in the range of 5.0x10^-13 to 1.0x10 ^-14 which is almost at least 1000 to 1500 times higher than proposed BSVI limit of 6.0x10 ^-11.

Fuel Economy trends

- For all the 3 vehicles, F.E. recorded in MIDC Cold cycles has been at least 2kmpl lesser that what was declared by Manufacturer at the time of Type Approval. This difference has come out probably due to road load equation values that were calculated as per WLTP procedure and are more representative of drag forces on real roads.

- However, Fuel Economy (F.E.) has come 0.5 to 1.0 kmpl better in WLTC cycle as compared to MIDC cycle for all the 3 vehicles. Please note that the WLTC does not include the Extra high speed section of that drive cycle.

5.2: Task 2: PEMS Testing

Following activities were planned under Task 2: -

- PEMS route test selection.

- The EU test route was to consist of urban driving followed by rural and motorway according to the shares specified and speed/acceleration patterns described in the EU legislation 2016/427 (first RDE regulatory package) and (EU) 2016/646 (second RDE regulatory package).

- IND test route was to be selected that did not follow the legislative RDE cycle but representative of real driving conditions in India. Vehicle had to follow local speed limits.

- Collection of Real Driving Emissions (RDE) over both the routes for all 3 vehicles.

- Perform data post processing and analysis as per the regulatory guidelines. This includes time alignment, drift correction, NOx corrections for temperature and humidity and instantaneous emission calculations.

Total number of RDE tests planned under Task2 is given as below:

Table 7: Tests under task 2

Vehicle	RDE as per European Union procedure	RDE as per Indian condition	Total
I20 Petrol	2	1	3
I20 Diesel	2	1	3
XUV 500	2	1	3
Total Tests			9

5.2.1 Task 2- Deliverables:

PEMS data collected, route test data, raw and processed (corrected, time aligned) in CSV format (1 Hz sampling rate) for all routes. General requirement for PEMS measurement were provided from ICCT based on guidelines from the draft Real Driving Emissions (RDE) PEMS measurement for passenger vehicles. List of parameters to be recorded is given below: -

Table 8: List of parameters to be recorded while RDE testing

S.NO	Parameter	Unit	Source	Possibility of measurement using PEMS (Yes/ No)
1	CO concentration	ppm	Analyzer	Yes
2	NOx concentration	ppm	Analyzer	Yes
3	NO/NO2 speciation	ppm	Analyzer	Yes
4	CO2 concentration	ppm	Analyzer	Yes
5	Exhaust gas flow	kg/h	EFM	Yes
6	Exhaust temperature	K	EFM	Yes
7	Ambient temperature	K	Sensor	Yes
8	Ambient Pressure	KPa	Sensor	Yes
9	Ambient Humidity	%	Sensor	Yes
10	Engine Torque	Nm	OBD Port	**Yes****
11	Engine Speed	RPM	OBD Port	Yes
12	Engine Fuel Flow	g/s	Fuel Flow Meter	Yes
13	Engine Coolant Temp	K	Sensor	Yes
14	Engine Intake Air Temp	K	Sensor	Yes
15	Vehicle ground speed	Km/h	GPS	Yes
16	Vehicle latitude/longitude	degree	GPS	Yes
17	Vehicle Altitude	Meter	GPS	Yes
18	EGR valve opening	% or on-off		Yes, External Tapping

**** Calculated Load from OBD was recorded instead of Engine torque as engine torque data was not available on OBD.**

5.2.2 Task 2- Test Setup and Methodology:

European (EU) RDE Test Route Selection:

Simulated European (EU) route for RDE testing started from ICAT and finished back at ICAT.

Route was selected considering following regulatory EU parameters:

- Route shall have minimum urban share of 29 % and max of 44 %, rural share as 33% +-10% & motorway share as 33% +-10%.
- Duration of trip in terms of kilometers shall be such that it covers minimum 16 kms of each urban, rural and motorway share.
- Total Trip Time Duration shall be b/w 90 -120 minutes.
- Average velocity over the complete route shall be b/w 15-40 km/h.

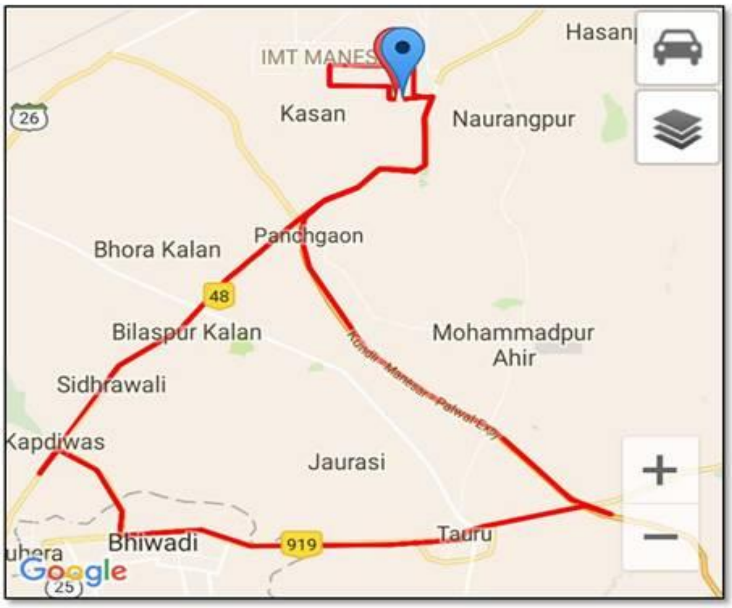


Figure 29: Route 1 (RDE EU)

Speed trace over the complete route for one vehicle (i20 Diesel) for route representation is shown below:

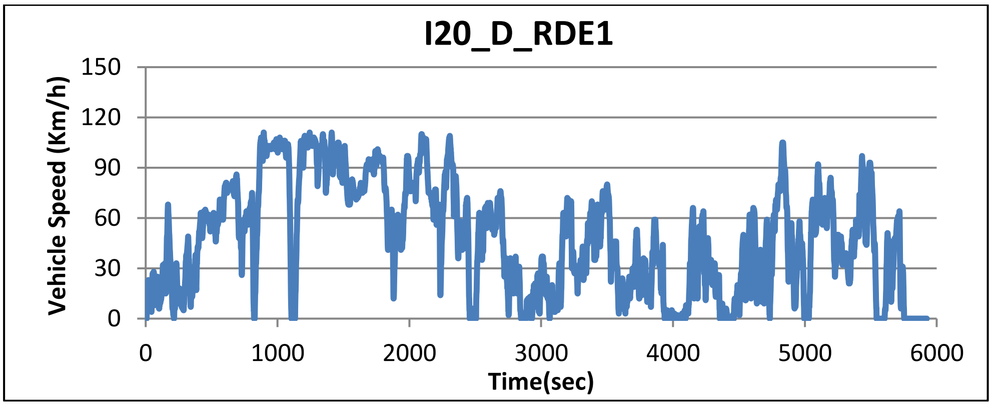


Figure30: Speed Trace of I20_D during EU RDE

Altitude trace over the complete route for one vehicle (i20 Petrol) for route representation is shown below:

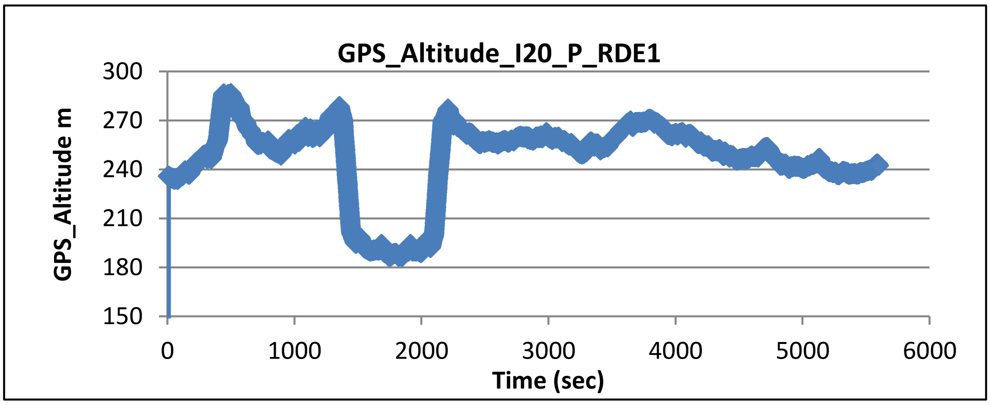


Figure 31: Altitude Trace of I20_P during EU RDE

Driving details of the complete route are as below:

Table 9: Details of EU conditions route

Location From	**Location To**	**Approx Distance (Kms)**	**Speed Ranges**
ICAT	National Highway-8 (NH-8)	1.0	Vehicle was driven in the range 0-90 kmph (i.e. urban and rural patches)
NH-8	Panchgaon	10.0	
Panchgaon	Kundi Manesar Palwal Expressway	20.0	Mainly Motorway speeds (90 kmph and above) were covered in this area.
Kundi Manesar Palwal Expressway	Areas of Tauru Village till back to NH-8 near to BML Munjal University (Kapdiwas area)	20.0	Vehicle was driven mainly in the range 0-90 kmph (i.e. urban and rural patches)
NH-8 (BML University)	ICAT	20.0	Vehicle was driven mainly in the range 0-90 kmph (i.e. urban and rural patches)
Total Approx Distance (km)		**71.0**	

INDIAN RDE ROUTE DETAILS:

Indian (IND) route was selected to reflect actual Indian road conditions, following local speed limits enroute. Vehicle was driven in three speed ranges (0-40, 40-60, 60-80 kmph).

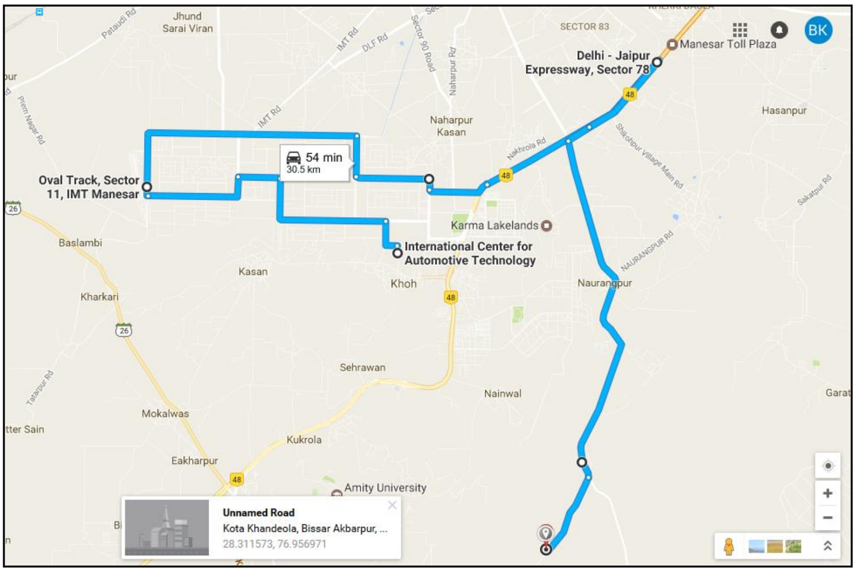


Figure 32: Route 2 (RDE IND)

Speed trace over the complete route for one vehicle (i20 Diesel) for route representation is shown below:

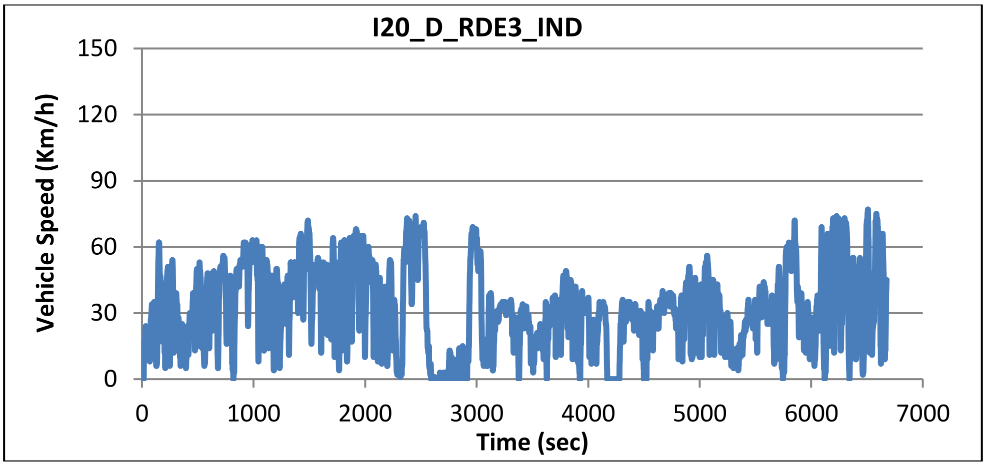


Figure 33: Speed Trace of I20_D during INDIAN RDE

Altitude trace over the complete route for one vehicle (i20 Petrol) for route representation is shown below:

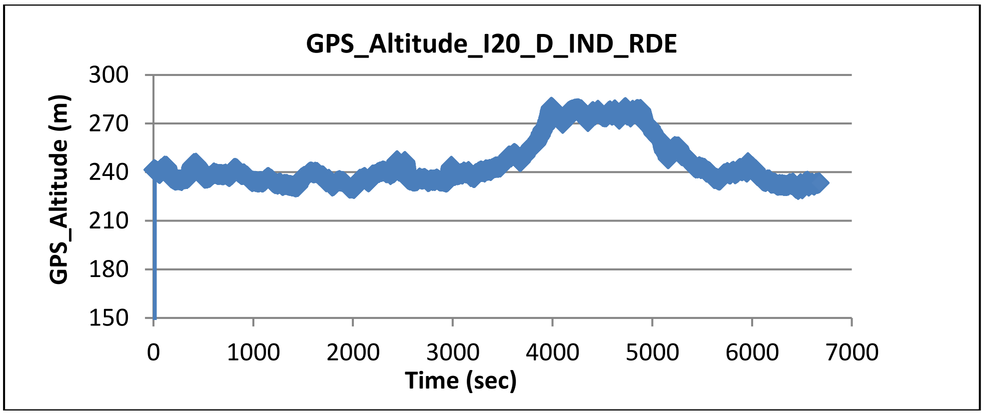


Figure 34: Altitude Trace of I20 Diesel during INDIAN RDE Test

Driving details of the complete route are as below:

Table 10: Details of IND conditions route

Location From	**Location To**	**Approx Distance (kms)**	**Speed Ranges**
ICAT	National Highway	15.0	Driven in range 0-80 kmph. It was easier to get speed above 40 kmph
NH-8	Naurangur village	8.0	Driven in range 0-80 kmph. It was easier to get speed above 40 kmph
Start of Naurangur village	Kota Village	10.0	Vehicle was driven in 0-40 Kmph speed range
Start of Kota Village	Back of Main road of NH-8	10.0	
Main road	ICAT	5.0	Driven in range of 0-80 kmph. It was easier to get speed above 40 kmph
Total Approx Distance (km)		**48.0**	

Difference b/w EU RDE and Indian RDE Routes:

Following were major differences b/w EU RDE & Indian RDE testing; rest test requirements & procedures were maintained same:

Table 11: Difference b/w EU RDE & Indian RDE Testing

S. No	Parameters	EU RDE Testing	Indian RDE Testing
1	Speed Limits	As per EU legislative requirements	As per local permissible limits in India i.e. 80 kmph
2	Driving shares speed Limits	Urban limit--- Up to 60 kmph Rural limit---- 60 to 90 kmph Motorway limit---90 to 135 kmph	Urban limit--- Up to 40 kmph Rural limit---- 40 to 60 kmph Motorway limit---60 to 80 kmph
3	Route Distance	Approx 70 kms	Approx 50 kms

General Guidelines for PEMS Testing:

In order to get accurate data, following were kept in mind:
- The vehicle was driven vehicle normally as per real driving conditions.
- Test fuel was always drawn from single commercial batch.
- No extra electrical load was placed on the vehicle’s battery while testing.
- Driver for all the tests was kept same except for XUV IND RDE.

Test Setup:

The following equipments were required to measure required data:
- PEMS (Portable Emission Measurement System)
- OBD data
- Ambient temperature and humidity sensor.
- GPS (Global Positioning System)
- Physical tapping to measure EGR signal or behavior
- Fuel flow meter

PEMS mounting and Set up:

The PEMS used for this project was an integrated system from AVL with advanced gas analyzes, exhaust mass flow meters, OBD data logging, weather station, and Global Positioning System (GPS).

PEMS is equipment that can be used to collect accurate real time pollutants emitted during RDE by the engine (CO, CO_2, NOx), and also log other associated data of engine, vehicle and ambient parameters. PEMS require 30 min. warm up time before starting the test procedure. As per EU procedure, after warm-up is completed pre-calibration check has to be done on PEMS before starting PEMS test. After the RDE test is completed, post-calibration check is done. Then, recorded data is post processed for time alignment, drift correction, wet-dry conditions, NOx correction for temperature and humidity. Same PEMS setup was mounted on all the three vehicles one by one.

Figure 35: PEMS setup on vehicles

PEMS equipment specifications are given in **Table 16** of **Annexure I.**

Gases used to calibrate PEMS analyzers for all the three vehicles for both EU & IND RDE tests are given in **Table 17** of **Annexure I.**

<u>EGR Signal Tapping:</u>

EGR signal tapping during RDE was done in same manner as described in Section 5.1.2 Task 1 - Test Setup and Methodology of this report.

<u>Fuel Flow meter:</u>

Specification of Fuel Flow meter used for I20_P RDE testing is shown in **Table 18** of **Annexure I**. Installation mounting pictures are given below: -

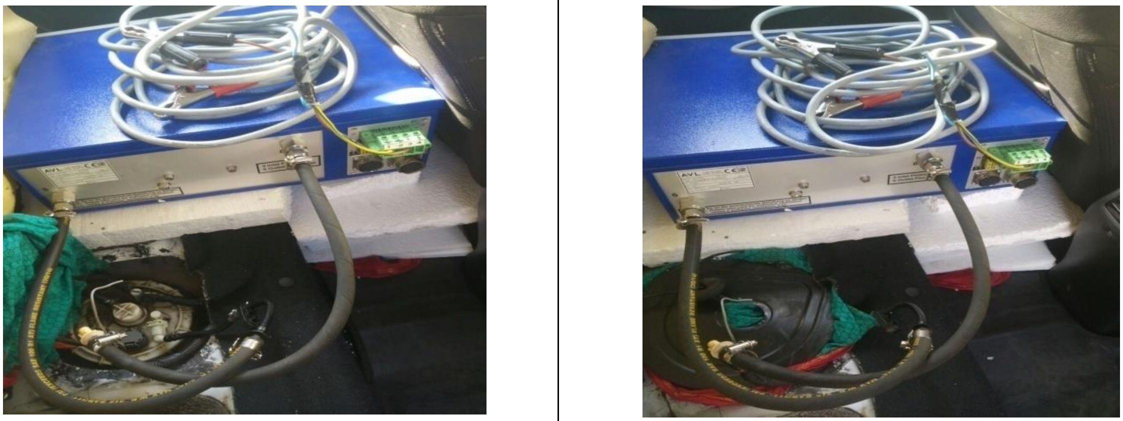


Figure 36: Fuel Flow Meter setup in I20_P

Specification of Fuel Flow meter used for I20_D and XUV500 RDE testing is given as shown in of **Table 19** of **Annexure I**. Installation mounting pictures are given below: -

Figure 37: Fuel Flow Meter setup in I20_D & XUV 500 respectively

5.2.3 Task 2- Results:

<u>CVS v/s PEMS correlation:</u>

Before starting RDE tests, it was required to check correlation between emissions results of Mass Bag Emission’s CVS (Constant Volume Sampler) and PEMS. For this purpose, PEMS was mounted on the vehicle and driven for WLTC Cold Test on Chassis Dynamometer. The tail pipe’s exhaust gases were first passed from PEMS Analyzers and then sent to CVS for Mass Emission Analyzers.

Finally, the total cycle emission results were calculated and compared for both CVS and PEMS. As agreed with ICCT, correlation of CVS and PEMS was done only in diesel vehicles viz. I20_D and XUV500. The correlation passed as per “Section 3.3 - Permissible tolerances for PEMS validation” of Appendix 3 of EU legislation 2016/427 (first RDE regulatory package).
Detailed results of correlation tests are given below: -

Table 12: I20_D CVS v/s PEMS Correlation

	CO	CO2	NOx
	g/Km	g/Km	g/Km
CVS Bag Results	0.042	129.58	0.304
PEMS Total Results	0.0468	136.83	0.3379
Absolute Difference w.r.t. CVS	4.8	7.25	33.9
% Difference w.r.t CVS	11.4%	5.6%	11.2%
Permissible Tolerance (max of)	+/- 150 mg/Km	+/- 10 g/Km	+/- 15 mg/Km
	or 15%	or 10%	or 15%
	PASS	PASS	PASS

Table 13: XUV 500 CVS v/s PEMS Correlation

	CO	CO2	NOx
	g/Km	g/Km	g/Km
CVS Bag Results	0.21	195.261	0.695
PEMS Total Results	0.252	207.895	0.7973
Absolute Difference w.r.t. CVS	42	12.63	102.3
% Difference w.r.t CVS	20.0%	6.5%	14.7%
Permissible Tolerance (max of)	+/- 150 mg/Km	+/- 10 g/Km	+/- 15 mg/Km
	or 15%	or 10%	or 15%
	PASS	PASS	PASS

Emission Results - Modal Traces:

I20 Petrol:

Second by second modal data was logged successfully for I20_P vehicle. Since for gasoline vehicles; CO emissions are more prominent so the detailed analysis for the same is shown in the figure below. The data shows that CO trace is relatively higher in EU RDE as compared to IND RDE for I20_Petrol.

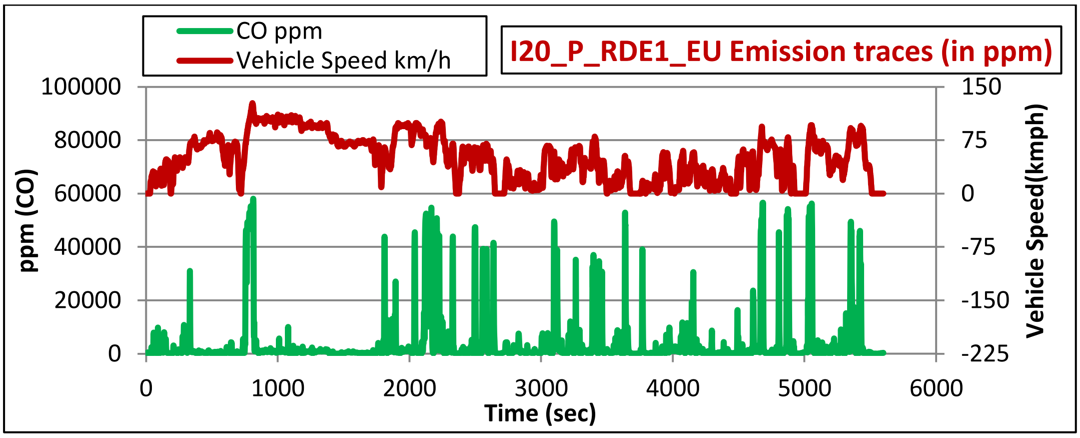


Figure 38: CO behavior in I20_P_RDE1_EU

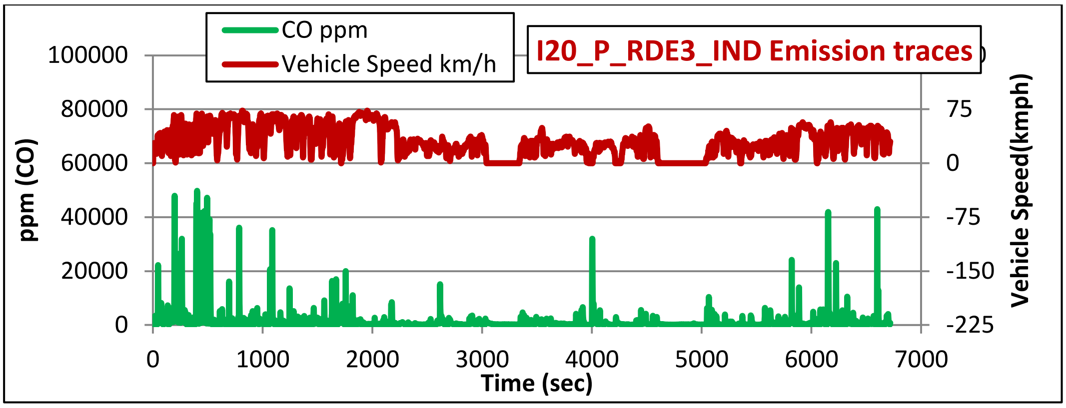


Figure 39: CO behavior in I20_P_RDE3_IND

<u>I20 Diesel:</u>

Second by second modal data was logged successfully for I20_D vehicle. Since for diesel vehicles; NOx emissions are more prominent so the detailed analysis for the same is shown in the figure below. The data shows that NOx trace is relatively higher in EU RDE as compared to IND RDE for I20_Deisel.

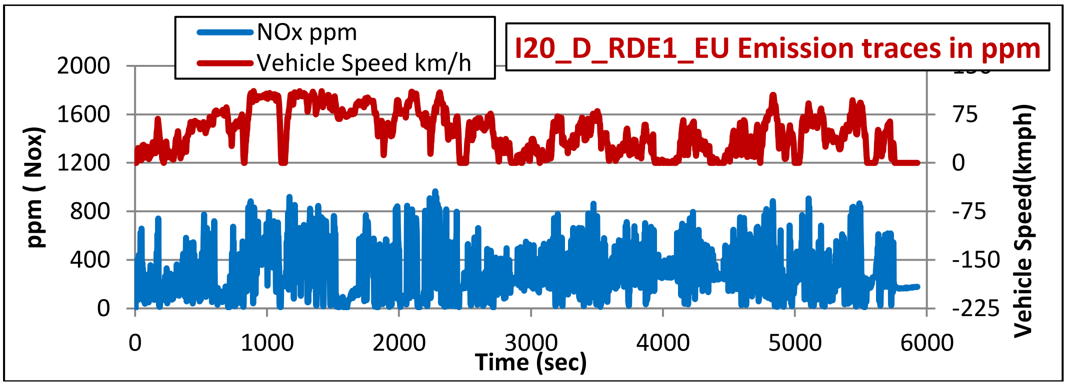


Figure 40: NOx behavior in I20_D_RDE1_EU

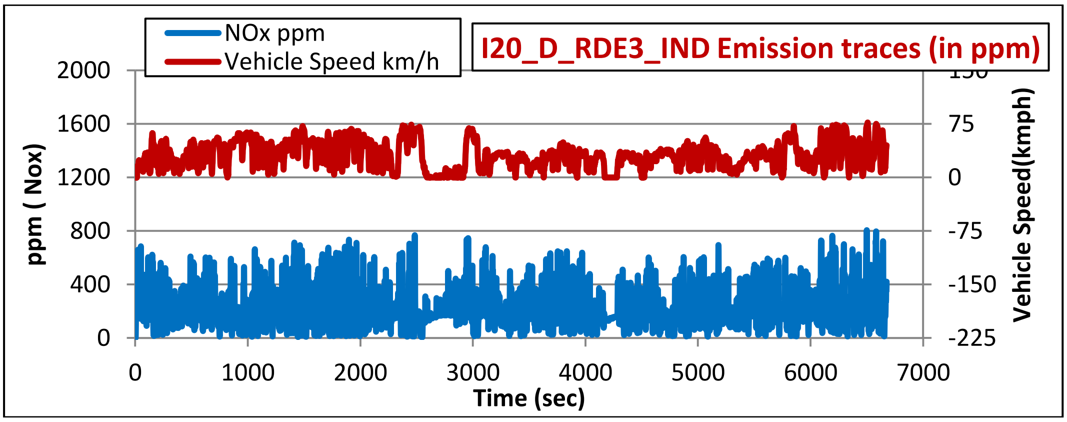


Figure 41: NOx behavior in I20_D_RDE3_IND

XUV500:

Second by second modal data was logged successfully for XUV500 vehicle. Detailed analysis for CO & NOx emissions is shown in the figure below. The data shows that NOx trace is relatively lower in EU RDE as compared to IND RDE for XUV500. However, CO trace has increased in EU RDE.

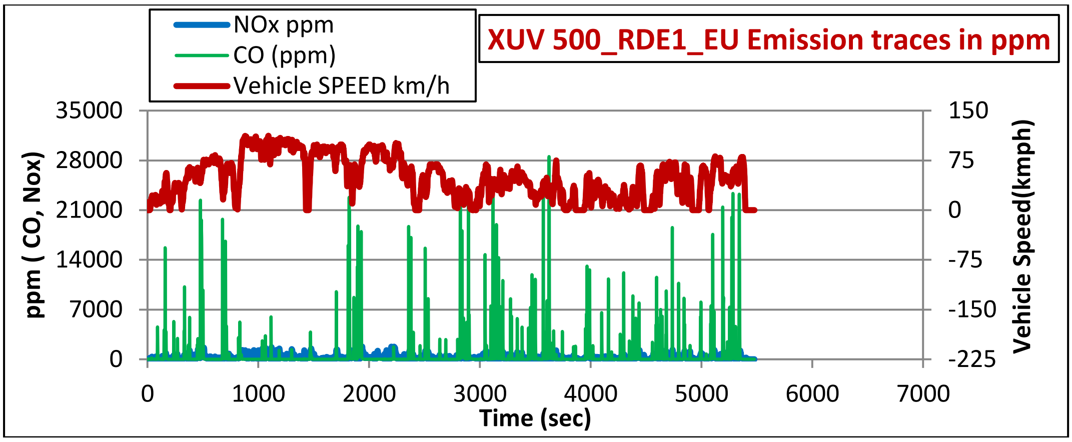


Figure 42: CO & NOx behavior in XUV500_RDE1_EU

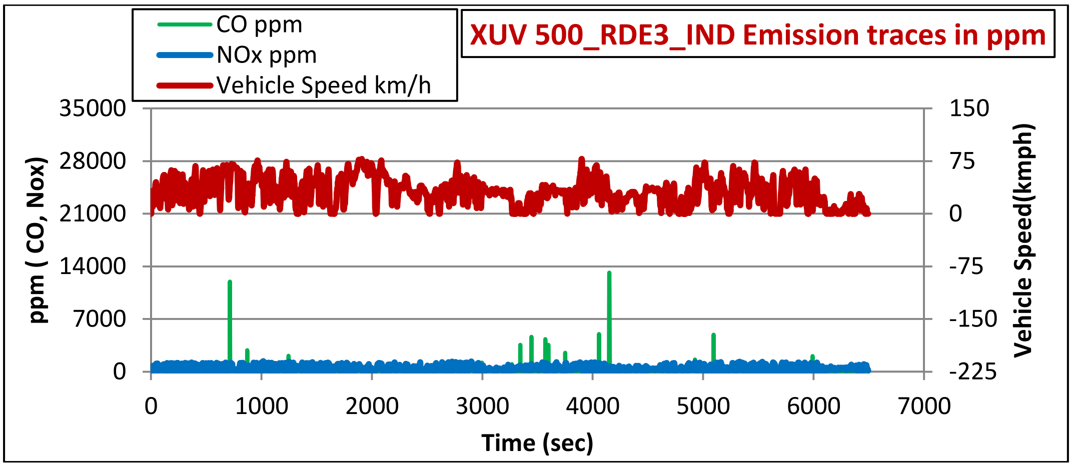


Figure 43: CO & NOx behavior in XUV500_RDE3_IND

Post processing of all vehicles using EMROAD:

All the EU regulatory RDE tests got passed as per procedures EU 2016/427 and EU 2016/646

Table 14: Status of EU RDE tests done

	I20_P RDE1 _EU	I20_P RDE2 _EU	I20_D RDE1 _EU	I20_D RDE2 _EU	XUV RDE 1_EU	XUV RDE 2_EU
Trip Shares						
Urban 34%+10%&>=29%	Pass	Pass	Pass	Pass	Pass	Pass
Rural 33% +-10%	Pass	Pass	Pass	Pass	Pass	Pass
Motorway 33% +-10%	Pass	Pass	Pass	Pass	Pass	Pass
Trip Distance, Time and Altitude						
Urban – Minimum 16 km	Pass	Pass	Pass	Pass	Pass	Pass
Rural – Minimum 16 km	Pass	Pass	Pass	Pass	Pass	Pass
Motorway – Minimum 16 km	Pass	Pass	Pass	Pass	Pass	Pass

	I20_P RDE1 _EU	I20_P RDE2 _EU	I20_D RDE1 _EU	I20_D RDE2 _EU	XUV RDE 1_EU	XUV RDE 2_EU
Total Trip Time Duration 90 -120 min	Pass	Pass	Pass	Pass	Pass	Pass
Delta - Start to End Altitude (max 100 m)	Pass	Pass	Pass	Pass	Pass	Pass
Urban Requirements						
Avg Velocity 15-40 km/h	Pass	Pass	Pass	Pass	Pass	Pass
Urban Stop time 6 -30%	Pass	Pass	Pass	Pass	Pass	Pass
Motorway Requirements						
5 Minutes >= 100 km/h	Pass	Pass	Pass	Pass	Pass	Pass
Velocity b/w 90-110 km/h	Pass	Pass	Pass	**Fail**	Pass	Pass
Test Completeness (CO2 Windows)						
Urban 15% Windows	Pass	Pass	Pass	Pass	Pass	Pass
Rural 15% Windows	Pass	Pass	Pass	Pass	Pass	Pass
Motorway 15% Windows	Pass	Pass	Pass	Pass	Pass	Pass
CO2 Normality(Normal Windows)						
Urban 50% in Primary Tolerance	Pass	Pass	Pass	Pass	Pass	Pass
Rural 50% in Primary Tolerance	Pass	Pass	Pass	Pass	Pass	Pass
Motorway 50% in Primary Tolerance	Pass	Pass	Pass	Pass	Pass	Pass
Acceleration points						
(a > 0.1 m/s²)>=150	Pass	Pass	Pass	Pass	Pass	Pass
Trip Validity va pos[95] (invalid if)						
v<=74.6km/h & va pos[95]>va_pos thrshld1	Pass	Pass	Pass	Pass	Pass	Pass
v>74.6 km/h & va pos[95]>va_pos thrshld2	Pass	Pass	Pass	Pass	Pass	Pass
Trip Validity RPA (invalid if)						
v <= 94.05 and RPA < RPA threshold	Pass	Pass	Pass	Pass	Pass	Pass
v > 94.05 and RPA < 0.025	Pass	Pass	Pass	Pass	Pass	Pass
Span Gas > 0.9 * 99th percentile						
NO [ppm]	Pass	Pass	Pass	Pass	Pass	Pass
NO2 [ppm]	Pass	Pass	Pass	Pass	Pass	Pass
CO [ppm]	Pass	Pass	Pass	Pass	**Fail**	Pass
CO2 [%]	Pass	Pass	Pass	Pass	Pass	Pass
% Mean Values >= 2 * Span Gas; <= 0.01	Pass	Pass	Pass	Pass	Pass	Pass

Deviations:

1) In I20_D RDE2_EU, max vehicle speed could not be taken beyond 107kmph due to traffic.

2) In XUV RDE1_EU, Span gas used was of little low range. In RDE2_EU, higher CO span gas was used.

For India Specific RDE tests, vehicles were driven as per real Indian Driving Conditions and as such no regulation was followed.

Emission Results - Total Bag:

Total Emission Results w.r.t BSIV emission results are given below for all 3 vehicles. The charts also show compilation of Fuel Economy measured from PEMS and the Flow Meter in kmpl.

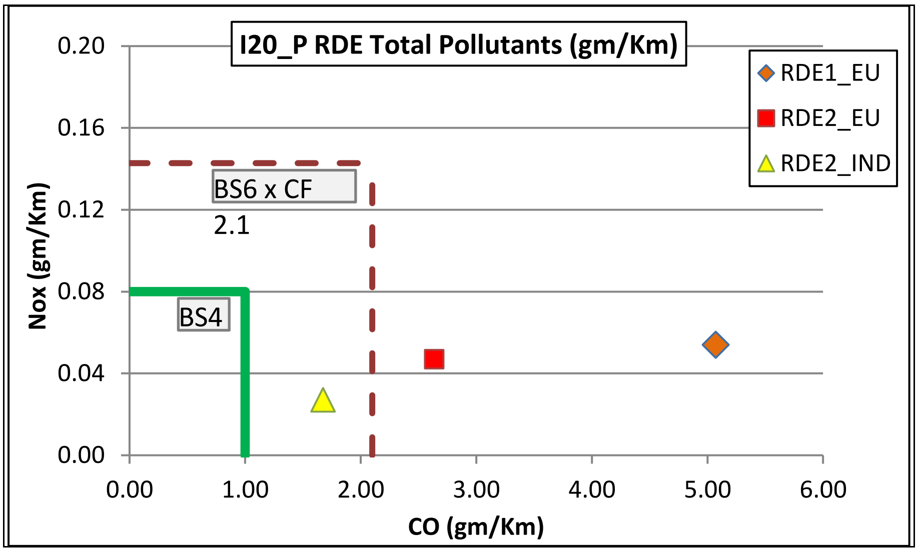


Figure 44: I20_P RDE total pollutants

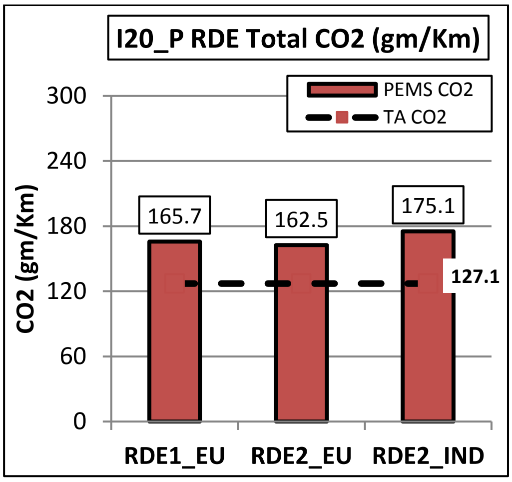


Figure 45: I20_P RDE total CO2

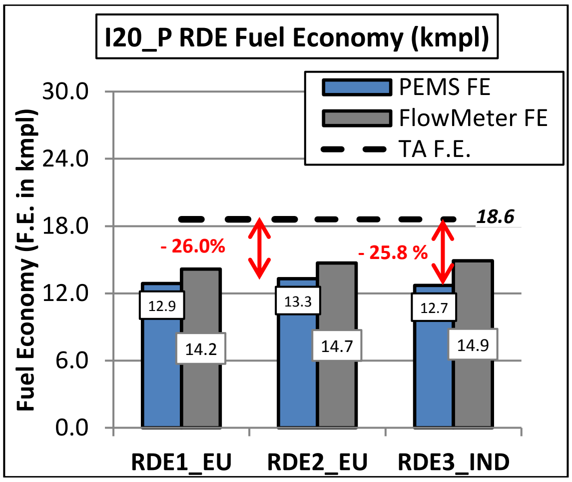


Figure 46: I20_P RDE Fuel Economy

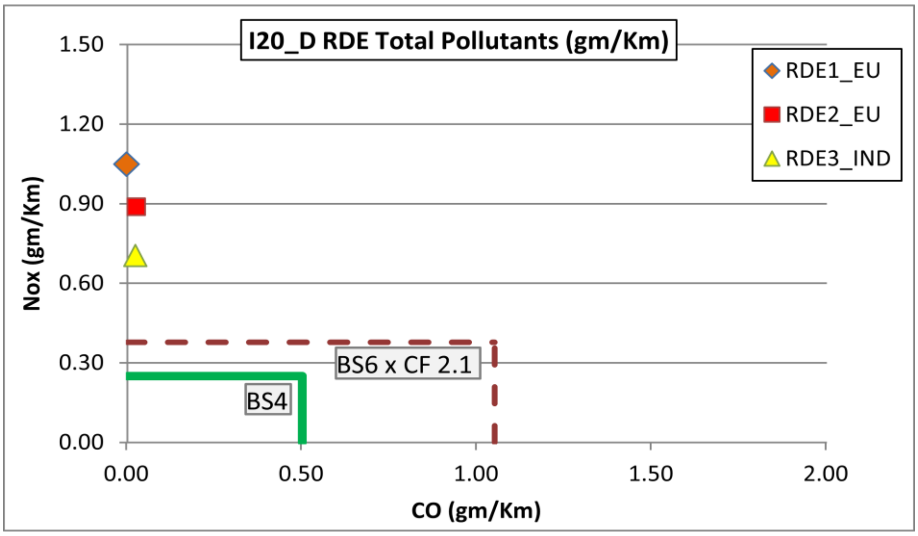


Figure 47: I20_D RDE total pollutants

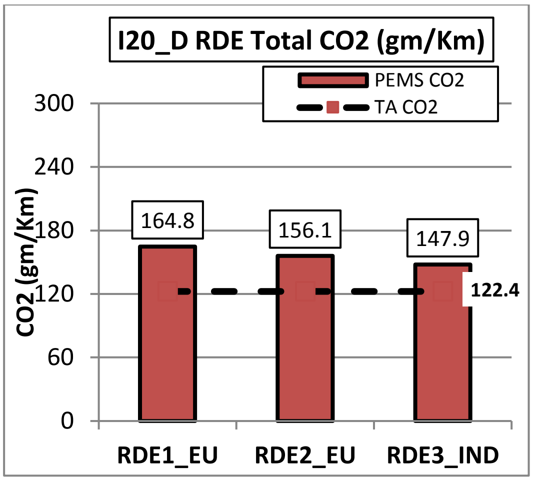


Figure 48: I20_D RDE total CO2

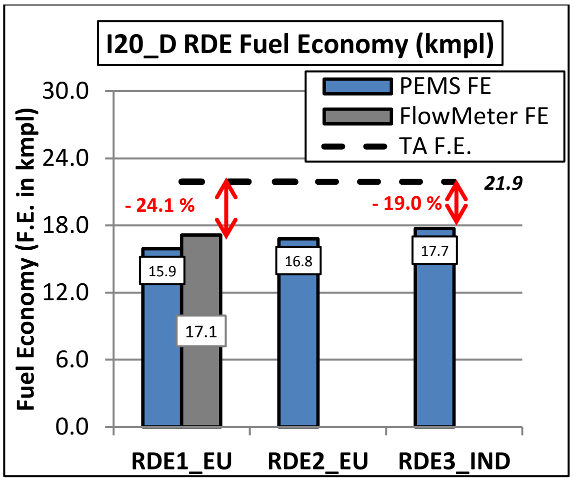


Figure 49: I20_D RDE Fuel Economy

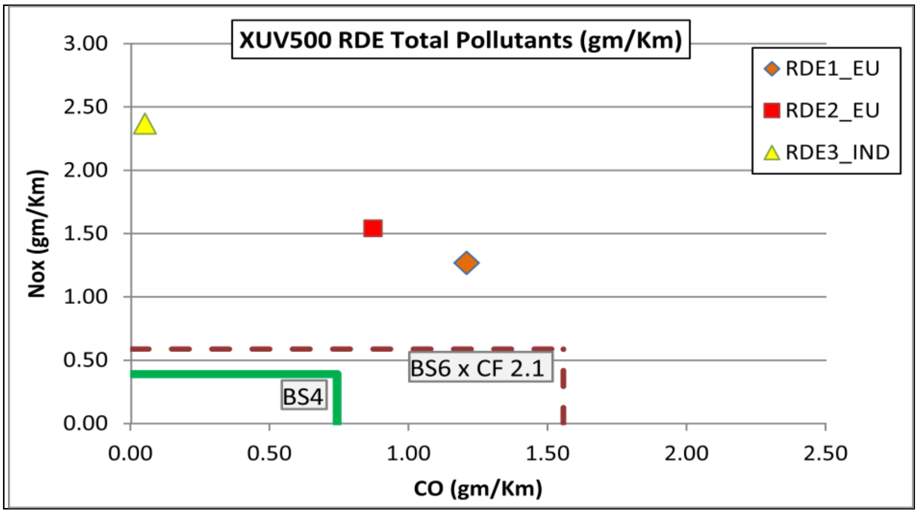


Figure 50: XUV 500 RDE total pollutants

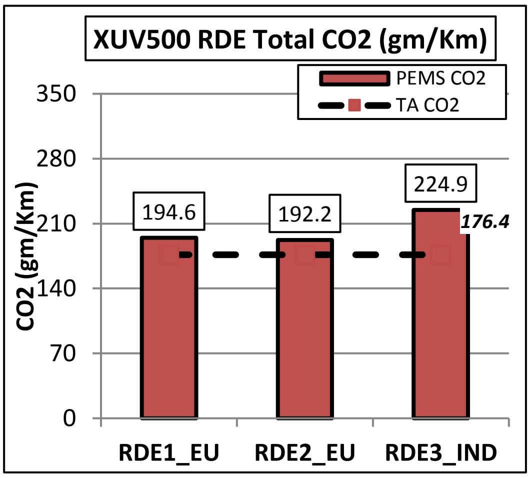


Figure 51: XUV 500 RDE total CO2

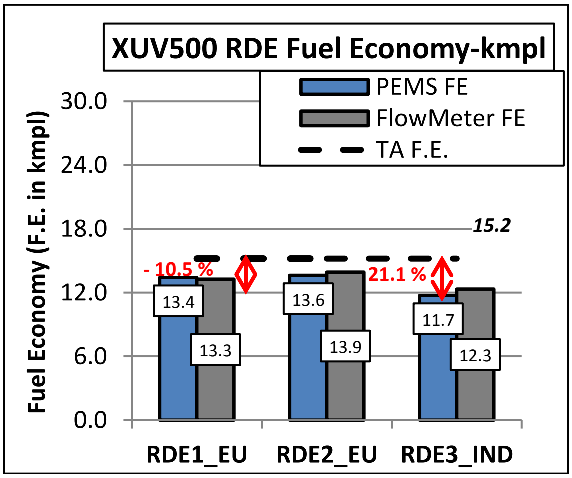


Figure 52: XUV 500 RDE Fuel Economy

5.2.4 Task2 - Conclusions:

- Overall, RDE testing completed successfully on all 3 vehicles.

Table 15: Factor of RDE over Lab Limits

	Factor of RDE w.r.t. BS IV limits		Factor of RDE w.r.t. proposed BS VI limits	
	CO	NOx	CO	NOx
I20 Petrol	**3.85**	0.63	**3.85**	0.74
I20 Diesel	0.05	**3.88**	0.05	**5.39**
XUV 500	1.40	**6.07**	1.40	**8.46**

- From the above table it can be concluded that RDE emissions of all the three vehicles are almost 4 to 6 times of BSIV Lab emission limits and up to 9 times of proposed BSVI Lab emission limits.

- Emissions are comparatively higher in EU RDE testing as compared to IND RDE testing for I20_P and I_20 D. However in case of XUV500, EU RDE has higher CO but lower NOx as compared to IND RDE.

- Fuel Economy (F.E.) has come 20 to 25 % lower in IND RDE tests for all 3 vehicles as compared to what was declared by manufacturer during Type Approval for all 3 vehicles.

<u>Challenges faced</u>:

- Initially XUV500 presented an EGR system malfunction, which was detected after failing the first MIDC tests and subsequently resolved. For details on pre- and post-repair emission performance refer Annexure-II

- Mounting of PEMS with all required adaptations without tempering vehicles was challenging since the vehicles have to be re-sold in market after completion of project. Also in India, trailer hitch option is not available. So, special arrangement was made to mount PEMS inside the vehicle behind the last row passenger seat and PEMS was fixed on the floor.

- Some tests were failed under European RDE requirements for speed and RPA due to heavy traffic on road and had to be repeated.

5.3 Comparison of laboratory and on-road emissions measurements:

<u>Pollutants Comparisons:</u>

<u>I20 Petrol:</u> Comparison of pollutants of i20 Petrol during CVS and RDE testing is presented here.

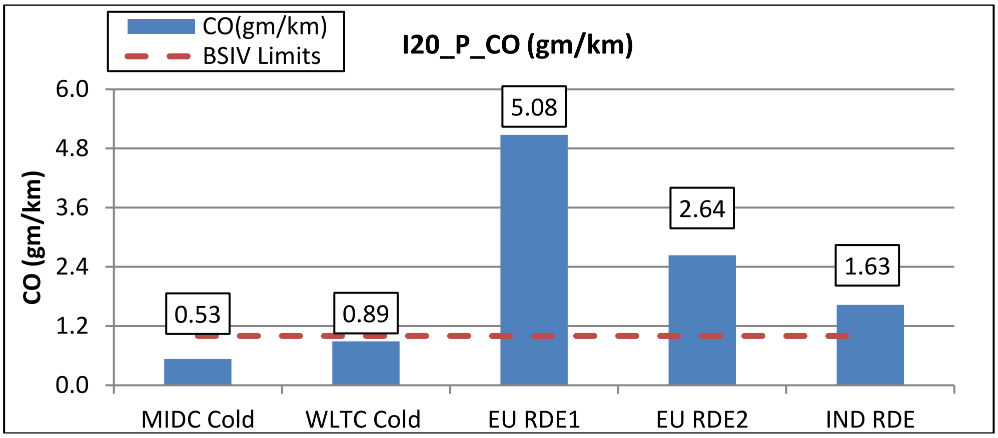


Figure 53: Comparison of CO for I20_P: Lab v/s RDE

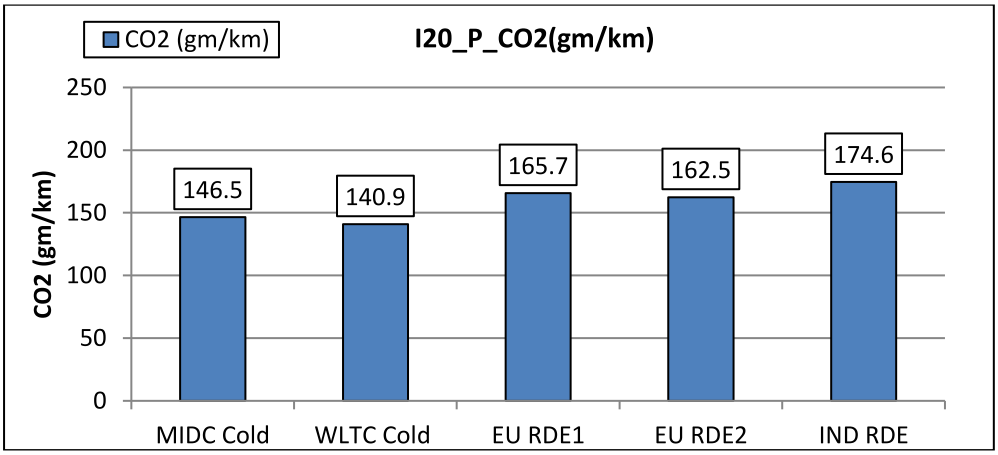


Figure 54: Comparison of CO2 for I20_P: Lab v/s RDE

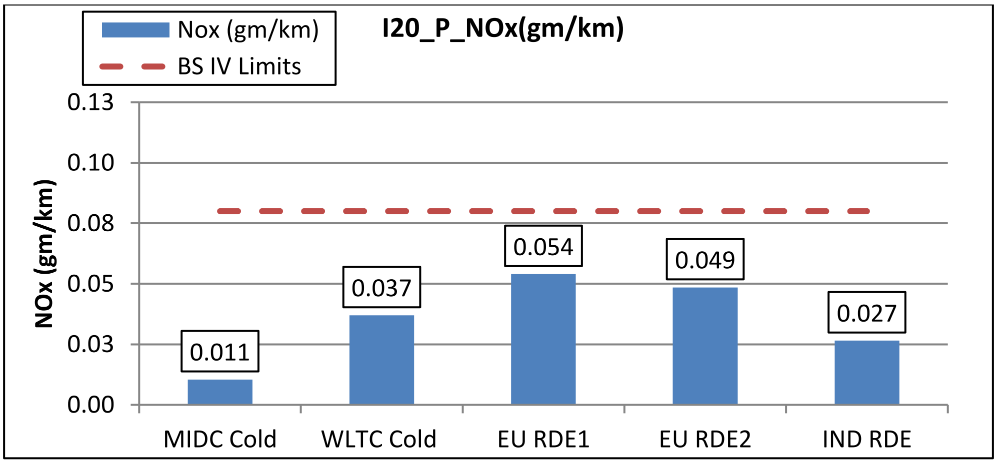


Figure 55: Comparison of NOx for I20_P: Lab v/s RDE

<u>I20 Diesel:</u> Comparison of pollutants of i20 Diesel during CVS and RDE testing is presented here.

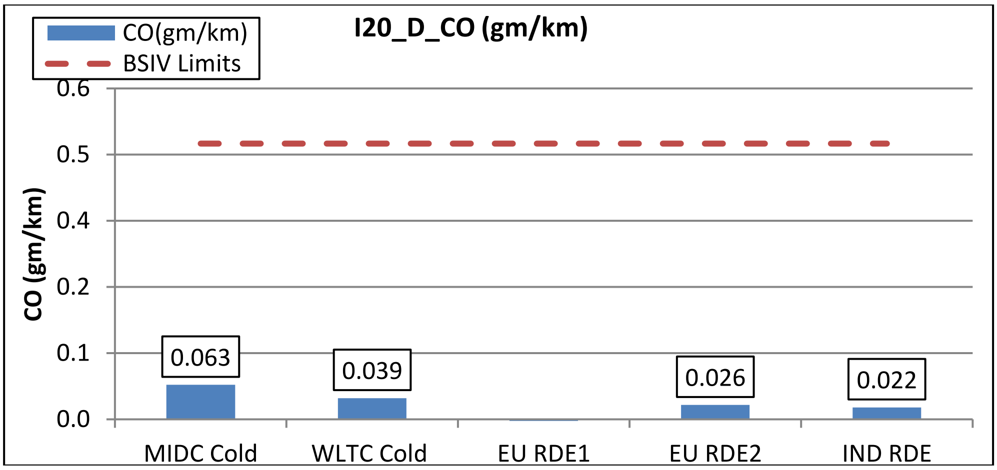


Figure 56: Comparison of CO for I20_D: Lab v/s RDE

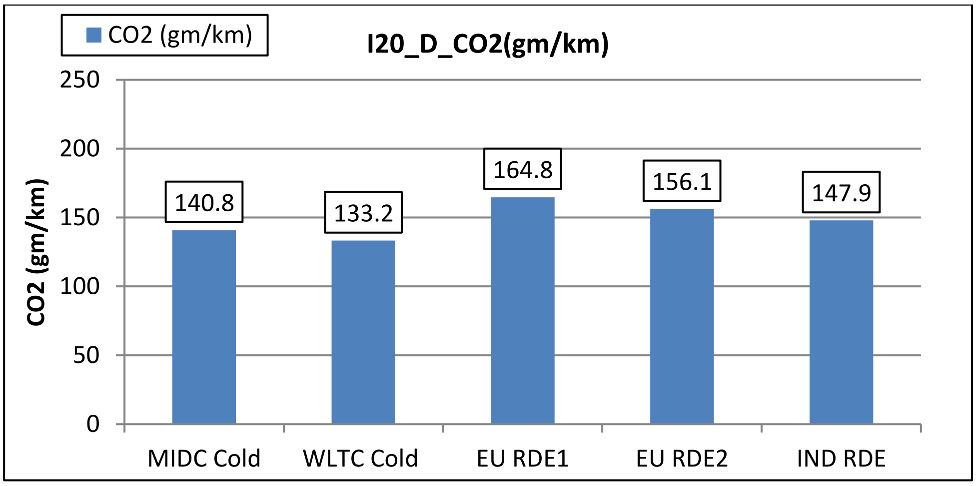


Figure 57: Comparison of CO2 for I20_D: Lab v/s RDE

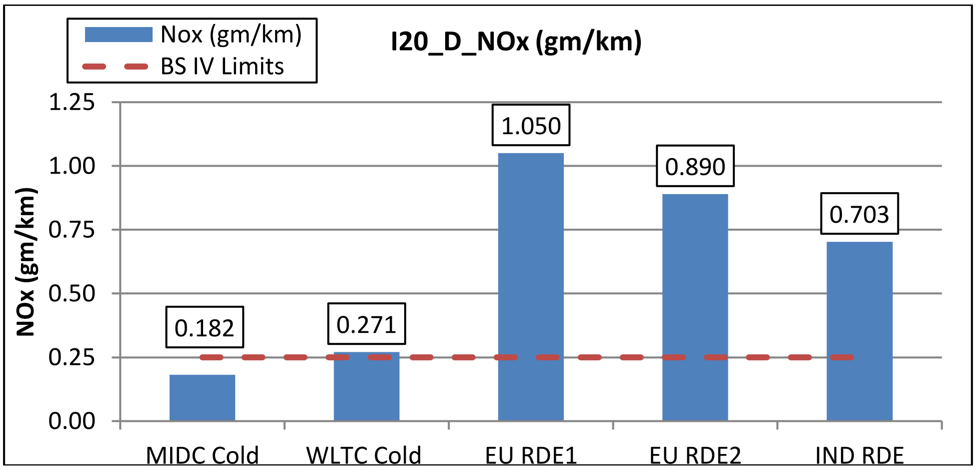


Figure 58: Comparison of NOx for I20_D: Lab v/s RDE

XUV500: Comparison of pollutants of XUV500 during CVS and RDE testing is presented here.

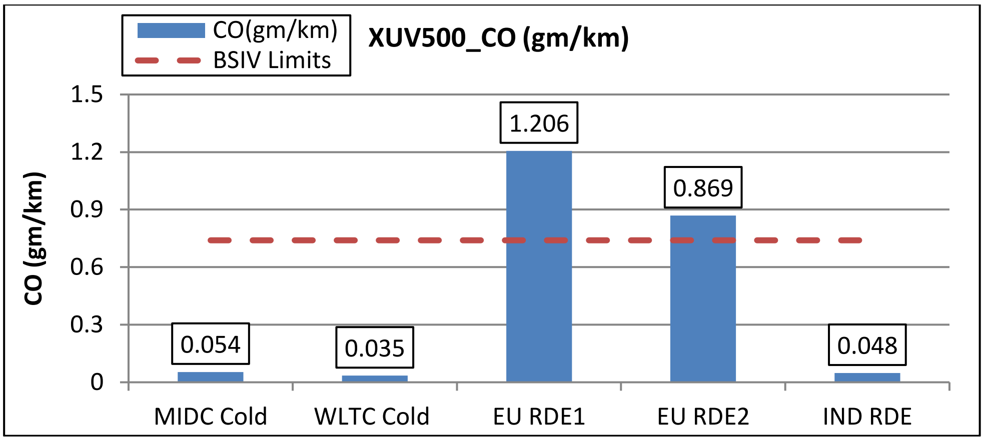


Figure 59: Comparison of CO for XUV500: Lab v/s RDE

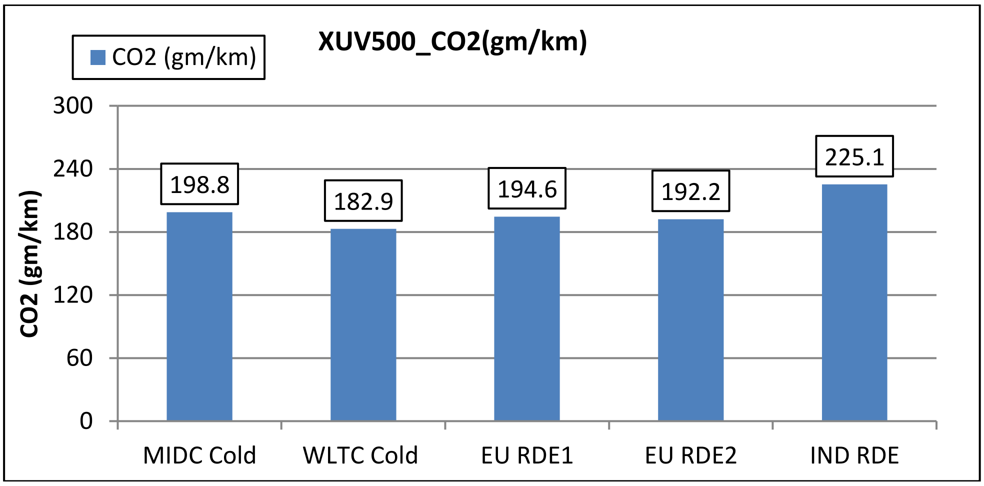


Figure 60: Comparison of CO2 for XUV500: Lab v/s RDE

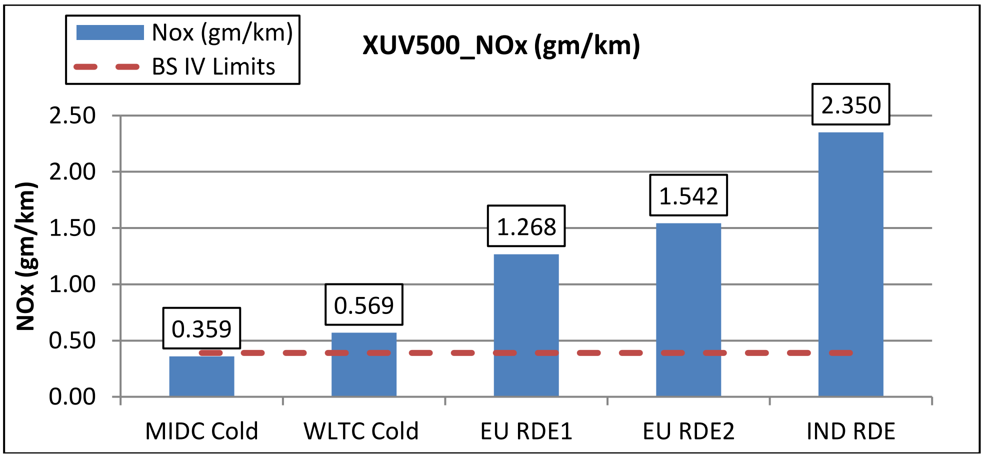


Figure 61: Comparison of NOx for XUV500: Lab v/s RDE

Annexure I

This Annexure contains specifications of equipments & calibration gases used during RDE testing:

Table 16: PEMS specifications

Operating temperature (ambient)	-10°C to 45°C -30°C to -10°C with additional insulating blanket
Storage temperature	-30 to +70°C(Oxygen sensor needs to be removed below 0°C and above 50°C)
Dimensions (w*h*d)	Measuring module: ~ 495*355*333 mm, with protection cover: ~ 590*480*447mm
Weight	< 30kg (NO_x Module)
Warm-up time @20°C ambient temp	< 1hr (ready for measurement)
Power demand	22 to 28V DC, appr. 220W @ 20°C ambient temperature (with 2m sample line and after warm up)
Sample flow rate	< 3.5l/min
Sampling Conditions	End of tail pipe, ±50mbar relative pressure
Inputs/Outputs electrical	1xHeated line connectors; 1x Ethernet (TCP/IP)
Analyzer Technologies	UV (NO/ NO_2); NDIR (CO/CO_2) ; Electrochemical: (O_2)
Measurement Range	0 -5,000 ppm (NO); 0 -2,500 ppm (NO_2) ; 0 -5 vol% (CO), 0 -20 vol% (CO_2)
Accuracy	CO:0 –1,499 ppm: +-30 ppm abs., 1,500 ppm –49,999 ppm: +-2% rel.; CO_2:0 –9.99 vol.%: +-0.1 vol.% abs., 10 -20 vol.%: +-2%rel. NO: 0–5,000 ppm: +-0.2% FS or +-2% rel. NO_2:0 –2,500 ppm: +-0.2% FS or +-2% rel.
Zero Drift	CO:20 ppm/8h CO_2:0.1 vol%/8h NO/ NO_2:2 ppm/8h
Span Drift	CO:≤ 20 ppm abs./8h or 2% rel./8h CO_2:≤ 0.1 vol% abs./8h or 2% rel./ 8h NO/ NO_2:≤ 1% rel./ week
Linearity	slope : 0,99 ≤ Slope ≤1,01, intercept ≤0,5 %, SEE: ≤1% of range and R^2: >= 0,999
Pneumatics Inputs/ Outputs	1x external calibration module 1x exhaust and drainage OUT
Heated Lines	Available lengths: ·1.2m Y-Type · 1.2 m Single · 2.5 m Single · 5.0 m Single T Adjustable: 70 –120°C

Table 17: List of calibration gases used for calibrating PEMS

<table>
<tr><th rowspan="1">Port/Bottle</th><th>Gases</th><th>I20_P</th><th>I20_D</th><th colspan="2">XUV 500</th></tr>
<tr><td>Port 1/Bottle 1</td><td>NO_2(ppm)</td><td>505</td><td>505</td><td colspan="2">2356</td></tr>
<tr><td rowspan="2">Port 2/Bottle 2</td><td rowspan="2">CO(ppm)</td><td rowspan="2">49200</td><td rowspan="2">4978</td><td>RDE 1</td><td>RDE 2&IND</td></tr>
<tr><td>4978</td><td>49200</td></tr>
<tr><td>Port 1/Bottle 3</td><td>NO(ppm)</td><td>4940</td><td>4940</td><td colspan="2">4940</td></tr>
<tr><td>Port 2/Bottle 4</td><td>CO_2(%)</td><td>19.9</td><td>19.9</td><td colspan="2">19.9</td></tr>
</table>

Table 18: Specifications of Fuel flow meter used in I20_P

Flow meter	servo-driven displacement counter according to the PLU measuring principle
Measurement range (type 075)	0.16…75 l/hr 0.12 ... 56 kg/h * (*at a density of 0.75 g/cm³)
Density meter (option):	500 ... 2000 kg/m³
Density measurement uncertainty	1 kg/m³
Measurement uncertainty (reproducibility of sensor calibration factors)	±0.1% (of reading)
Rise time	t10 ... t90 < 125 ms
Ambient temperature	-10 °C ... +50 °C
Media temperature	-10 °C ... +60 °C (+80 °C in case of minimum 1/3 tankful)
Measuring media (measuring module):	FlexFuel: Gasoline, standard grade, super grade fuels (leaded/unleaded) with any alcoholic admixtures as well as equivalent testing fluids Methanol, ethanol etc. up to 100 % as well as equivalent testing fluids Diesel and equivalent testing fluids, Biodiesel (device has to be purged after use; follow operating instructions)
Signal Output	RS 232 with AK-protocol Frequency out (approx. 0 … 80 kHz) TTL Open collector RS 422
Operating voltage:	12 VDC, option: 24 VDC
Dimensions (measuring module):	470 x 170 x 550 mm (W x H x D)
Weight (measuring module):	15 kg

Table 19: Specifications of Fuel flow meter used in I20_D and XUV 500

Measurement Parameters	Fuel Volume, Fuel Temperature (Option), Fuel Pressure (Option)
To be used with	gasoline , diesel, alcohol based and bio fuel
Quick lock Connectors	NW 5.8
Measuring ranges	Flow Rate 0.5…250l/h
Fuel Temperature	-20…+75 °C (option)
Fuel Pressure	0…6bar relative (option)
Measuring Accuracy	Fuel Volume ± 0.5% of reading (in the range 1…50l/h)
Fuel Temperature	K-Type DIN IEC 584. Class 1 (others on request) (option) PT 100
Fuel Pressure	± 0.25% or ± 0.15% full scale (option)
resolution	Fuel Volume 330x10-3 ml
Fuel Temperature	depending on the user's data acquisition
Fuel Pressure	depending on the user's data acquisition
Drop of Pressure	30kPa at 50l/h , 80 kPa at 120 l/h usually compensated by internal pump
Operation Pressure	sub pressure approx. -0.5 bar up to 5 bar in error condition max. 6 bar
Shock and vibration resistance	3G
Media Temperature	short term 120 °C at approx. 70°C and above, gas bubbles can develop in the fuel. Presence of gas bubbles can result in diminished accuracy
Ambient Temperature range (Operation)	-20…+70°C
Fuel Filter	one filter on each side
relative humidity	80%
Operating voltage	provided by signal processor
Degree of ingress protection	IP 44
Favourite mounting / operating direction	not defined
Dimension	183 × 106 × 94 mm
Weight	2.0 kg

Annexure-II

XUV 500 EGR Issue

XUV500 vehicle initially had problem with EGR valve not getting open significantly. The EGR malfunction was detected first during MIDC testing after failing the emission test. OBD scan tool also didn't show any fault code. Emissions were comparatively higher than BS IV legislative limits (as per MIDC cold start emission values).

The vehicle was diagnosed by service center and it was found out that vacuum hose of EGR line was punctured of EGR. The issue was resolved by replacing the hose and EGR started behaving normally.

Following is emission comparison of XUV500 before and after repair of EGR:

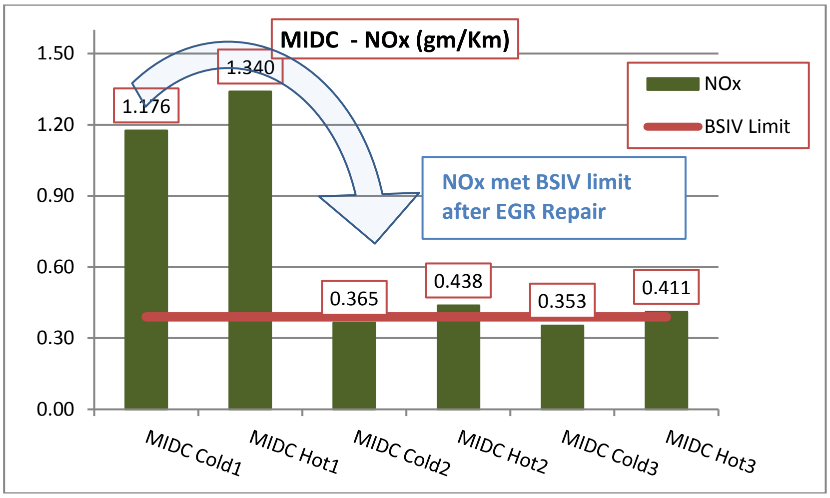


Figure 62: Comparison of NOx before and after repair of EGR

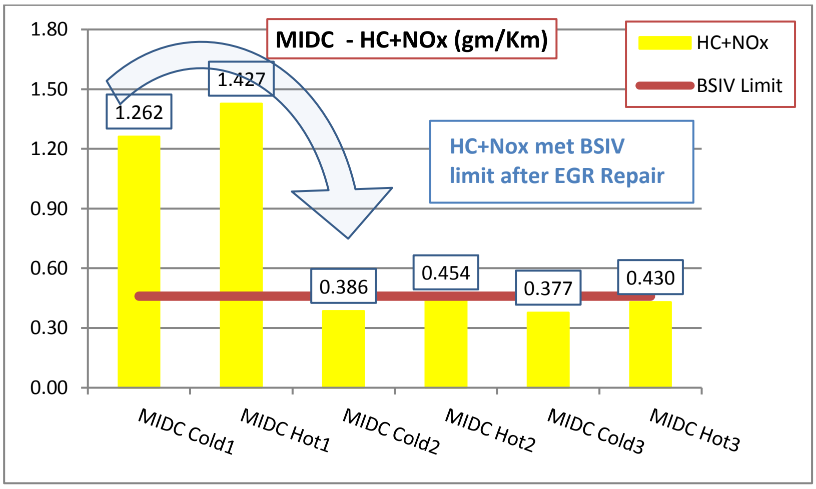


Figure 63: Comparison of HC+NOx before and after repair of EGR

6. References:

1. https://www.dieselnet.com/standards/cycles/wltp.php
2. http://www.transportpolicy.net
3. Internal Combustion Engine Fundamentals. by John B. Heywood
4. https://www.unece.org/trans/main/wp29/meeting_docs_grpe.html

------------------------------------ DT - report--

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BRIJ MOHAN (GET)		**GAURAV GUPTA (Manager PT-CoE)**	**Page 48 of 48**