

### Appendix A: Uncertainty Analysis

All measuring devices and measurements have measuring range, resolutions and accuracy. The measuring instruments may be so precise giving similar and closer readings but may not be 100% accuracy. Hence, a term called uncertainty due to accuracy of measuring instruments is always exists. Error and uncertainties in experiments are associated with various primary experimental measurements that may arise from instruments selection, calibration, environment and testing procedure. Hence uncertainty analysis is important to provide accuracy of experimental results. Table below gives accuracy of various measuring devices.

Uncertainties are calculated for different parameters [Brake Power (BP), brake thermal efficiency (BTHE), brake specific fuel consumption (BSFC)] based on measured value and net possible errors in measuring parameters and are as below.

$$\% \text{ Error in measured value} = \frac{\text{Net possible error}}{\text{Measured value}} \times 100$$

Net possible error: Accuracy of measuring instrument

Measured value: Calculated value of parameters from measuring instruments

Uncertainty is mostly found in parameters mentioned below:

- **Direct Measured Parameters** Emissions, Load, Speed
- **Calculated Parameters** (Brake power, Brake thermal efficiency, Brake specific fuel consumption, Mechanical, Volumetric and Thermal efficiency)

For direct measured parameters uncertainty is based on accuracy of readings. It can be calculated by standard deviation to the root of number of samples taken. While uncertainty of calculated parameters is calculated from root mean square of partial derivatives of measurement parameter multiplied by accuracy of parameters. The details are as mentioned below.

$$\text{Uncertainty} = \frac{\text{Resolution}}{\text{Range}} \times 100$$

Table 6-1 shows the uncertainty of various measuring instruments which will be helpful to calculate the other parameters uncertainty.

Table 6-1: Uncertainty of various measuring Instruments

Measurement	Unit	Range	Range	Resolution	Uncertainty (%)
Temperature	°C	0-1200	1200	0.05	0.004
Load (L)	Kg	Max 50	50	0.25	0.500
Fuel Flow (mf)	kg/hr	1.01	1.01	0.01	0.990
air flow (ma)	kg/hr	23.1	23.1	0.5	2.165
Speed (N)	rpm	400-6000	6000	0.25	0.004

**Uncertainty of Brake Power**

$$brake\ power = \frac{2\pi NT}{60}$$

$$\begin{aligned} \text{Uncertainty of BP} &= \text{Square root of } ((\Delta N/N)^2 + (\Delta L/L)^2) \\ &= \text{Square root of } ((0.5 \times 0.5) + (0.004 \times 0.004)) \\ &= 0.50 \end{aligned}$$

**Uncertainty of Specific Fuel Consumption**

$$bsfc = \frac{\text{mass of fuel}}{bp}$$

$$\begin{aligned} \text{Uncertainty of BSFC} &= \text{Square root of } ((\Delta N/N)^2 + (\Delta L/L)^2 + (\Delta mf/mf)^2) \\ &= 1.11 \end{aligned}$$

**Uncertainty of Brake Thermal Efficiency**

$$BTE = \frac{bp * 3600 * 100}{\text{mass of fuel} * \text{Calorific Value}}$$

$$\begin{aligned} \text{Uncertainty of BTE} &= \text{Square root of } ((\Delta N/N)^2 + (\Delta L/L)^2 + (\Delta mf/mf)^2 + (\Delta LHV)^2) \\ &= 1.49 \text{ (Where, uncertainty of CV is assumed to be 1\%)} \end{aligned}$$

To find out the uncertainty of NO<sub>x</sub>, CO, HC, CO<sub>2</sub> emission, standard deviation method is used. Standard diesel fuel is used to take all the readings.

### *Uncertainty analysis of NOx emission*

The below Table 6-2 shows specifications of gas analyser

Table 6-2: AVL444N Gas Analyzer Accuracy

<b>Parameter</b>	<b>Unit</b>	<b>Measurement</b>	<b>Resolution</b>	<b>Accuracy</b>
CO	% Vol	0 to 15% Vol	0.01% Vol	<0.6 %: ±0.03 % Vol ≥0.6 %: ±5 % ind. Val
HC	ppm Vol	0 to 20,000	1 ppm /10 ppm <2000 RPM / >2000RPM	<200ppm Vol: ±10 ppm Vol ≥200ppm Vol: ±5 % ind. Val
CO <sub>2</sub>	% Vol	0 to 20	0.1 % Vol	<10%: ±0.5 % Vol ≥10%: ±5 % ind. Vol
O <sub>2</sub>	% Vol	0 to 25	0.01 % Vol	<2%: ±0.1 % Vol ≥2%: ±5% ind. Vol
NO	ppm Vol	0 to 5000	1 ppm Vol	<500ppm Vol: ±50 ppm Vol ≥500ppm Vol: ±10% of ind. Val
Speed	RPM	400 to 6000 RPM	1 RPM	±1% of ind. Vol
Oil Temp	°C	0 to 125	1°C	±4 °C
Lambda (λ)	-	0 to 9.999	0.001	Calculations of CO, CO <sub>2</sub> , HC, O <sub>2</sub>

Table 6-3: Uncertainty of NOx emission

<b>NOx ppm</b>	<b>Accuracy NOx</b>	<b>Deviation</b>	<b>Square</b>	<b>Uncertain Value %Vol</b>	<b>Relative Uncertainty (%)</b>
95	0.01	0.95	0.9025	0.95	1
380	0.01	3.8	14.44	3.80	1
517	0.1	51.7	2672.89	51.70	10
772	0.1	77.2	5959.84	77.20	10
1046	0.1	104.6	10941.16	104.60	10
1287	0.1	128.7	16563.69	128.70	10
105	0.01	1.05	1.1025	1.05	1
261	0.01	2.61	6.8121	2.61	1
613	0.1	61.3	3757.69	61.30	10
981	0.1	98.1	9623.61	98.10	10
1076	0.1	107.6	11577.76	107.60	10
1341	0.1	134.1	17982.81	134.10	10
109	0.01	1.09	1.1881	1.09	1
293	0.01	2.93	8.5849	2.93	1
778	0.01	7.78	60.5284	7.78	1
1070	0.1	107	11449	107.00	10
1128	0.1	112.8	12723.84	112.80	10
1411	0.1	141.1	19909.21	141.10	10
153	0.01	1.53	2.3409	1.53	1
439	0.01	4.39	19.2721	4.39	1
922	0.1	92.2	8500.84	92.20	10
1213	0.1	121.3	14713.69	121.30	10
1260	0.1	126	15876	126.00	10
1540	0.1	154	23716	154.00	10
Average Uncertainty				68.49	6.625

Uncertainty of NOx emission is  $\pm 68.49$  ppm

*Uncertainty analysis of CO emission*

Table 6-4: Uncertainty of CO emission

<b>CO % vol.</b>	<b>Accuracy</b>	<b>Deviation</b>	<b>Square</b>	<b>Uncertain Value %Vol</b>	<b>Relative Uncertainty (%)</b>
0.28	0.03	0.0084	7.056E-05	0.01	3
0.32	0.03	0.0096	9.216E-05	0.01	3
0.25	0.03	0.0075	5.625E-05	0.01	3
0.29	0.03	0.0087	7.569E-05	0.01	3
0.56	0.03	0.0168	0.0002822	0.02	3
0.86	0.03	0.0258	0.0006656	0.03	3
0.16	0.03	0.0048	2.304E-05	0.00	3
0.21	0.03	0.0063	3.969E-05	0.01	3
0.28	0.03	0.0084	7.056E-05	0.01	3
0.32	0.03	0.0096	9.216E-05	0.01	3
0.58	0.03	0.0174	0.0003028	0.02	3
0.95	0.03	0.0285	0.0008123	0.03	3
0.18	0.03	0.0054	2.916E-05	0.01	3
0.22	0.03	0.0066	4.356E-05	0.01	3
0.23	0.03	0.0069	4.761E-05	0.01	3
0.26	0.03	0.0078	6.084E-05	0.01	3
0.51	0.03	0.0153	0.0002341	0.02	3
1.1	0.03	0.033	0.001089	0.03	3
0.13	0.03	0.0039	1.521E-05	0.00	3
0.16	0.03	0.0048	2.304E-05	0.00	3
0.19	0.03	0.0057	3.249E-05	0.01	3
0.21	0.03	0.0063	3.969E-05	0.01	3
0.58	0.03	0.0174	0.0003028	0.02	3
1.2	0.03	0.036	0.001296	0.04	3
<b>Average Uncertainty</b>				<b>0.01</b>	<b>3</b>

Uncertainty of CO emission is  $\pm 0.01$

*Uncertainty analysis of HC emission*

Table 6-5: Uncertainty of HC emission

<b>HC ppm</b>	<b>Accuracy</b>	<b>Deviation</b>	<b>Square</b>	<b>Uncertain Value %Vol</b>	<b>Relative Uncertainty (%)</b>
34	0.05	1.7	2.89	<b>1.70</b>	<b>5</b>
38	0.05	1.9	3.61	<b>1.90</b>	<b>5</b>
44	0.05	2.2	4.84	<b>2.20</b>	<b>5</b>
64	0.05	3.2	10.24	<b>3.20</b>	<b>5</b>
65	0.05	3.25	10.5625	<b>3.25</b>	<b>5</b>
87	0.05	4.35	18.9225	<b>4.35</b>	<b>5</b>
15	0.05	0.75	0.5625	<b>0.75</b>	<b>5</b>
18	0.05	0.9	0.81	<b>0.90</b>	<b>5</b>
32	0.05	1.6	2.56	<b>1.60</b>	<b>5</b>
48	0.05	2.4	5.76	<b>2.40</b>	<b>5</b>
59	0.05	2.95	8.7025	<b>2.95</b>	<b>5</b>
81	0.05	4.05	16.4025	<b>4.05</b>	<b>5</b>
19	0.05	0.95	0.9025	<b>0.95</b>	<b>5</b>
29	0.05	1.45	2.1025	<b>1.45</b>	<b>5</b>
36	0.05	1.8	3.24	<b>1.80</b>	<b>5</b>
48	0.05	2.4	5.76	<b>2.40</b>	<b>5</b>
62	0.05	3.1	9.61	<b>3.10</b>	<b>5</b>
81	0.05	4.05	16.4025	<b>4.05</b>	<b>5</b>
11	0.05	0.55	0.3025	<b>0.55</b>	<b>5</b>
19	0.05	0.95	0.9025	<b>0.95</b>	<b>5</b>
18	0.05	0.9	0.81	<b>0.90</b>	<b>5</b>
44	0.05	2.2	4.84	<b>2.20</b>	<b>5</b>
35	0.05	1.75	3.0625	<b>1.75</b>	<b>5</b>
52	0.05	2.6	6.76	<b>2.60</b>	<b>5</b>
<b>Average Uncertainty</b>				<b>2.16</b>	<b>5</b>

Uncertainty of HC emission is  $\pm 2.16$

## Uncertainty Analysis of Smoke Emission

Table 6-6: Uncertainty of Smoke emission

Smoke	Accuracy NOx	Dev	Square	Uncertain Value %Vol	Relative Uncertainty (%)
7.6	0.1	0.76	0.5776	0.76	10
13.2	0.1	1.32	1.7424	1.32	10
14.3	0.1	1.43	2.0449	1.43	10
18.1	0.1	1.81	3.2761	1.81	10
26.5	0.1	2.65	7.0225	2.65	10
29.9	0.1	2.99	8.9401	2.99	10
6.1	0.1	0.61	0.3721	0.61	10
11.9	0.1	1.19	1.4161	1.19	10
14	0.1	1.4	1.96	1.40	10
19.5	0.1	1.95	3.8025	1.95	10
24.4	0.1	2.44	5.9536	2.44	10
26.4	0.1	2.64	6.9696	2.64	10
2.4	0.1	0.24	0.0576	0.24	10
6.5	0.1	0.65	0.4225	0.65	10
8.4	0.1	0.84	0.7056	0.84	10
13.6	0.1	1.36	1.8496	1.36	10
18.1	0.1	1.81	3.2761	1.81	10
27.3	0.1	2.73	7.4529	2.73	10
2.2	0.1	0.22	0.0484	0.22	10
7.6	0.1	0.76	0.5776	0.76	10
9.7	0.1	0.97	0.9409	0.97	10
11	0.1	1.1	1.21	1.10	10
16.2	0.1	1.62	2.6244	1.62	10
21	0.1	2.1	4.41	2.10	10
<b>Average Uncertainty</b>				<b>1.48</b>	<b>10</b>

Uncertainty of Smoke emission is  $\pm 1.48$

So all the uncertainties are summarised as shown in the Table 6-7.

Table 6-7: Summary of estimated uncertainty

<b>Sr</b>	<b>Parameter</b>	<b>Uncertainty</b>	<b>Unit</b>
1	Brake Power	$\pm 0.050$	kW
2	Brake Thermal Efficiency	$\pm 1.49\%$	BTHE (%)
3	Brake Specific Fuel Consumption	$\pm 1.11\%$	kg/kWhr
4	Hydrocarbons emissions	$\pm 2.16$	ppm
5	Carbon monoxide	$\pm 0.01$	% Vol
6	Nitric Oxide	$\pm 68.49$	ppm
7	Smoke	$\pm 1.48$	% Volume

## Appendix B: Fuel Test Report



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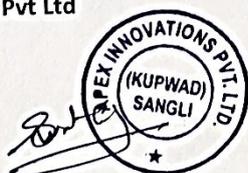
### Test Report

Sample Name	Diesel, Madhuca Longifolia Biodiesel, Biodiesel-Diesel blends		
Sample No	S192-197	Date	12.10.2022
Sample by	Mr. Asfakahemad A Shekh		
Guide	Dr. Nikul K Patel		
Research Center	Faculty of Technology & Engineering, M.S. University of Baroda Kalabhavan, Baroda - 390 001		

Sample/ Properties	Acid Value	Free Fatty Acid	Density At 25C	LCV Calorific Value	HCV Calorific Value	Flash Point	Fire Point	Kinematic Viscoisty @40°C	Dynamic Viscosity @40°C
Unit	mg of KOH gm of oil	%	kg m <sup>3</sup>	Calorie gm - 0 <sub>c</sub>	Calorie gm - 0 <sub>c</sub>	°C	°C	cSt	cP
ASTM Standard	D6751	--	D287	D 4809	D 4809	D93- 58T	D93- 58T	D445	D445
StD1	0.6	0.3	816	10,236	10822	53	56	2.09	1.73
B10	0.73	0.37	826	9958	10544	61	67	2.79	2.30
B20	0.79	0.4	828	9687	10273	68	74	2.93	2.43
B30	0.89	0.45	832	9523	10109	71	77	3.08	2.56
B100	1.31	0.56	871	9470	10056	101	110	4.98	4.34
RawOil	2.20	1.10	910	8967	9553	256	270	39.6	36.0

**Nomenclature:** B10:10% Madhuca Longifolia biodiesel and 90% Diesel (v/v), B20: 20% Madhuca Longifolia biodiesel and 80% Diesel (v/v), B30: 30% Madhuca Longifolia biodiesel and 70% Diesel (v/v), B100:100% Madhuca Longifolia biodiesel, Raw oil: 100% Madhuca Longifolia Raw oil

For Apex Innovations Pvt Ltd



## Appendix C: Calibration Reports.

Gas analyser calibration report.

 <b>Test/Calibration Report</b>											
<b>Ref:</b> 05_22_YKK_CC061_DLR_Apex_Sangli_444N_CAL <span style="float: right;"><b>Date:</b> 06-10-2022</span>											
1.0	<b>Component : GAS ANALYSER</b> <b>Model Name:</b> AVL 444N – 4 Gas Analyzer <b>Model Sr. No.:- 3504</b>										
2.0	<b>Test sponsored by: M/s. Apex Innovations Pvt. Ltd.</b> <b>Location: - E-9/1, MIDC, Kupwad, District Sangli 416436</b>										
3.0	<b>Objective of the Test :</b> To carry out Physical check and calibration of gas Analyzer as per the test procedure specified in annexure 1 of CMVR/TAP 115-116 Part-8										
4.0	<b>Detailed Observations:</b> 4.1 <b>Checking of supply/Earthing:</b> OK 4.2 <b>A) Checking of Accessories</b>										
	<table border="1"> <tr><td>1. Leak Test Cap</td><td>OK</td></tr> <tr><td>2. Power supply</td><td>OK</td></tr> <tr><td>3. Filters</td><td>OK</td></tr> <tr><td>4. Sampling hose &amp; probes</td><td>OK</td></tr> </table>	1. Leak Test Cap	OK	2. Power supply	OK	3. Filters	OK	4. Sampling hose & probes	OK		
1. Leak Test Cap	OK										
2. Power supply	OK										
3. Filters	OK										
4. Sampling hose & probes	OK										
	<b>B) Functional Check</b>										
	<table border="1"> <tr><td>1. Leak Test</td><td>OK</td></tr> <tr><td>2. Auto Zero Test</td><td>OK</td></tr> <tr><td>3. Printer Check</td><td>OK</td></tr> <tr><td>4. Date/Time Check</td><td>OK</td></tr> <tr><td>5. Sampling Pipe(Leakage/Damage)</td><td>OK</td></tr> </table>	1. Leak Test	OK	2. Auto Zero Test	OK	3. Printer Check	OK	4. Date/Time Check	OK	5. Sampling Pipe(Leakage/Damage)	OK
1. Leak Test	OK										
2. Auto Zero Test	OK										
3. Printer Check	OK										
4. Date/Time Check	OK										
5. Sampling Pipe(Leakage/Damage)	OK										
	<b>C) Span Calibration</b>										
	<table border="1"> <tr><td>1. Details of the Gas Concentration: CO-3.54%, CO2-14.06%, HC-2025ppm</td></tr> <tr><td>2. Calibration gas cylinder no. :32638</td></tr> <tr><td>3. Calibration gas cylinder make : Chemtron Science Laboratories Pvt. Ltd.</td></tr> </table>	1. Details of the Gas Concentration: CO-3.54%, CO2-14.06%, HC-2025ppm	2. Calibration gas cylinder no. :32638	3. Calibration gas cylinder make : Chemtron Science Laboratories Pvt. Ltd.							
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2. Calibration gas cylinder no. :32638											
3. Calibration gas cylinder make : Chemtron Science Laboratories Pvt. Ltd.											
	<b>Result : OK</b>										
4.3	<b>Electrical Calibration : Ok</b>										
5.0	<b>One no of petrol vehicle checked for idling Emission measurement.</b>										
6.0	<b>Conclusion : M/C working Ok</b>										
7.0	<b>Calibration due date: 05-10-2023</b>										
	 <b>Signature &amp; seal of Manufacturer/Supplier</b>										
	<table border="0"> <tr> <td style="vertical-align: top;">                     AVL India Pvt. Ltd.                      ICC Devi Gaurav Tech Park, 2<sup>nd</sup> Floor, Unit No.201-C                      Next to Indian Card Clothing Co. Ltd. Pimpri,                      Pune 411015 Maharashtra INDIA                      www.avl.com                 </td> <td style="vertical-align: top; text-align: right;">                     AVL India Pvt. Ltd.                      376-377, Udyog Vihar, Phase-IV Gurgaon, Haryana – 122015                      Phone : +91-124-4090300 Fax : +91-124-2455273                      www. Avl.com                 </td> </tr> </table>	AVL India Pvt. Ltd. ICC Devi Gaurav Tech Park, 2 <sup>nd</sup> Floor, Unit No.201-C Next to Indian Card Clothing Co. Ltd. Pimpri, Pune 411015 Maharashtra INDIA www.avl.com	AVL India Pvt. Ltd. 376-377, Udyog Vihar, Phase-IV Gurgaon, Haryana – 122015 Phone : +91-124-4090300 Fax : +91-124-2455273 www. Avl.com								
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Date: 01.04.2023

## **Calibration Certificate**

### **To Whomsoever It May Concerned**

Sub: Calibration of Engine set up supplied available in Research Assistance Lab (RAL)

We refer Calibration and servicing of following engine set ups manufactured by Apex Innovations Pvt Ltd and available in Research Assistance Lab (RAL).

- 1) Computerised research engine setup, Single cylinder, four strokes, VCR, EGR, Multifuel Research Engine set up (Product 240)
- 2) Computersied Research engine, single cylinder, four strokes, VCR, CRDI with Open ECU setup (Product 244)

We hereby declare that above engine setup are serviced by us on date 31.03.2023, We have checked and calibrated temperature ( $\pm 0.5\%$ ), load ( $\pm 0.25\%$  of F.S), fuel flow ( $\pm 0.1\%$  of span), air flow ( $\pm 0.5\%$ ), water flow ( $\pm 2\%$  of full), speed ( $\pm 0.25\%$ ), measuring sensors. The parameters measured are within specified accuracy range of the respective sensors.

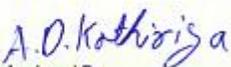
This calibration certificate is valid for the period of 06 months from the date of issue.

For Apex Innovations Pvt Ltd



**Ashok Mulay (Director)**

## Appendix D: Laboratory Test Report

		<b>ECO EARTH TECHNOLOGIES</b> (Analytical Laboratory Division) ISO 9001:2015, ISO 45001:2018 & ISO 14001:2015 Certified Company (GPCB RECOGNIZED SCHEDULED - II ENVIRONMENTAL AUDITOR) MAF&CC/GPCB RECOGNIZED LABORATORY UNDER ENVIRONMENT (PROTECTION) ACT, 1986 Plot No. 3202/A/2/1, T-1, Multilevel Shed, Near Advance Paint, GIDC Ind. Estate, Ankleshwar - 393 002, Dist. Bharuch, Gujarat, India. ☎ : +91 9601758907, 9409133000		
<b>Test Report / Certificate</b> <b>Chemical Analysis of Water / Waste water</b>				
Report No	EET22582300013705	Date of Report	21.12.2023	
<b>SAMPLE DETAILS</b>				
1	Name & Address of Company	M/S Government Engineering College, Bharuch Near K J Polytechnic, Opp.- Govt. Guest House, Old National Highway-8, Bholav, Bharuch, Gujarat, India		
2	Sample ID	3	Client Representative	
4	Sample Receive Date	5	Test Requirement	
6	Analysis Commenced on	7	Analysis Completed on	
8	Name of Sample	9	Sample Collected By	
10	ETP / STP Status	11	Sample Category	
12	Packing Condition & Quantity	Sealed		
13	Environment Condition During Sampling	-		
14	Environment Condition During Testing	25 ± 3 °C		
<b>TEST RESULT</b>				
Sr. No.	Parameter	Unit	Result	Test Method
1	Nitrite (NO <sub>2</sub> )	mg/L	4.24	APHA : (4500 NH <sub>3</sub> ) 23 <sup>rd</sup> Edition
2	Nitrate (NO <sub>3</sub> )	mg/L	0.53	APHA : (4500 NH <sub>3</sub> ) 23 <sup>rd</sup> Edition
<small>[ND - Not Detect, BDL - Below Detection Limit]</small> <b>Note:</b> 1). Reports may be reproduced, if required, but only in full and only with written approval of the laboratory. 2). Re analysis sample will be done, if requested within in 15 days from the date of reporting of sample if the sample are not consumed during analysis. 3). The result reported above relate to the sample identified under sample details.				
Analysed By 		Checked By 		For Eco Earth Technologies  Authorized Signatory
End of the Test Report				

## Appendix E: Anti-Plagiarism Report

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  - Bibliographic material
  - Submitted Works database
  - Manually excluded sources