Appendix –I

Engine Specifications

Make of the Engine : Kirloskar, TV1

General Details : Four Stroke, Compression ignition, Constant speed, Vertical, Water cooled, Computerized diesel engine

No. of Cylinders : One

Bore : 87.5 mm

Stroke : 110 mm

Swept Volume : 661 cc

Compression Ratio : 17.5:1

Rated Output : 5.2 KW at 1500 rpm

Injection Nozzle : 3 hole

Fuel Injection Pressure : 205 bar

Dynamometer : Eddy current, water cooled, with loading Unit

Propeller shaft : With universal joints

Air box : MS fabricated with orifice meter and U-tube manometer

Fuel tank : Capacity 15 Lit with glass fuel metering Column

Calorimeter : Type pipe in pipe out

Piezo sensor : Range 5000 PSI, with low noise cable

Crank angle sensor : Resolution 1 Deg, Speed 5500 rpm with TDC pulse
Engine Indicator : Input peizo sensor, crank angle sensor, Communication RS 232

Engine interface : Input RTDs, Thermocouples, Air flow, Fuel flow, Load cell, Output 0-5 V

Temperature sensor : Type RTD, PT 100 and thermocouple, Type K

Load sensor : Load cell, type strain gauge, range 0-50 Kg

Fuel flow transmitter : DP transmitter, range 0-500 mm WC

Rotameter : Engine Cooling 40-400 LPH, calorimeter 10-100 LPH

Pump : Type Monoblock

Add on card : Resolution 12 bit, 8/16 input, Mounting PCI slot

Software : “Enginesoft” Engine performance analysis Software

Overall dimensions : W 2000 X D 2500 X H 1500 mm

Optional : Computerized diesel injection pressure measurement

Computer : IBM, P IV Processor

Gross volume : 1.33 m³

Gross weight : 619 Kg

Net weight : 543 Kg

Water supply : Continuous, clean and soft water supply @ 1000 LPH, at 10 m. head is provided with a tap of 1” BSP size
### Appendix –II

#### Components Details and Instrumentation

<table>
<thead>
<tr>
<th>Component</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dynamometer</strong></td>
<td>Make Saj test plant Pvt. Ltd., Model AG10, Type Eddy current Dynamometer</td>
</tr>
<tr>
<td><strong>Loading Unit</strong></td>
<td>Make Apex, Model AX-155. Type constant Speed, Supply 230V, AC.</td>
</tr>
<tr>
<td><strong>Propeller shaft</strong></td>
<td>Make Hindustan Hardy Spicer, Model 1260, Type A</td>
</tr>
<tr>
<td><strong>Manometer</strong></td>
<td>Make Apex, Model MX-104, Range 100-0-100 mm, Type U tube, Conn. 1/4`` BSP hose back side, Mounting panel</td>
</tr>
<tr>
<td><strong>Fuel measuring unit</strong></td>
<td>Make Apex, Glass, Model: FF0.012</td>
</tr>
<tr>
<td><strong>Piezo sensor</strong></td>
<td>Make PCB Piezotronics, Model HSM111A22, Range 5000 psi, Diaphragm stainless steel type &amp; hermetic sealed</td>
</tr>
<tr>
<td><strong>White coaxial Teflon cable</strong></td>
<td>Make PCB piezotronics, Model 002C20, Length 20 ft, Connections one end BNC plug and other end 10-32 micro</td>
</tr>
<tr>
<td><strong>Crank angle sensor</strong></td>
<td>Make Kubler-Germany Model 8.3700.1321.0360 Dia: 37mm Shaft Size: Size 6mmxLength 12.5mm, Supply Voltage 5-30V DC, Output Push Pull (AA,BB,OO), PPR: 360, Outlet cable type axial with flange 37 to 58 mm</td>
</tr>
<tr>
<td><strong>Engine indicator</strong></td>
<td>Make-Cuadra, Model AX-104, Type Duel channel</td>
</tr>
<tr>
<td><strong>Engine interface</strong></td>
<td>Make-Cuadra, Model AX-408, No of channels 8</td>
</tr>
</tbody>
</table>
**Temperature sensor**: Make Radix, Type K, Ungrounded, Sheath Dia.6mmX110mmL, SS316, Connection 1/4"BSP (M) adjustable compression fitting

**Exhaust Gas Temperature**: RTD measurement

**Load sensor**: Make Sensotronics Sanmar Ltd., Model 60001, Type S beam, Universal, Capacity 0-50 kg

**Fuel flow transmitter**: Make Yokogawa, Model EJA110-EMS-5A-92NN, Calibration range 0-500 mm H2O, Linear Output

**Rotameter**: Make Eureka Model PG 3, Range 10-100 lph, Connection ½" BSP vertical, screwed, Packing neoprene

**Inlet Manifold Pressure**: U-Tube Manometer

**Measurement**

**Air Flow Measurement**: Digital Air Flow Meter

**Pump**: Make Q Tech, Model SP04, Head 24 m, Cap 1020 lph, HP 0.5, Size 1" x 1", Single Phase 230 V AC

**Add on card**: Make Dynalog, Model – PCI-1050, 12- Bit
Appendix –III

Smoke Meter Specifications

Name: AVL Smoke Meter
Model: 437 C
Manufacturer: AVL India Private Limited,
Community Shopping Centre,
Sector C, Pocket – 9,
Vasant Kunj, New Delhi -110 070.

Specifications:

Basic Operating Principle: The opacity is the extinction of light between Light source and receiver.

Accuracy and Reproducibility: 1 % Full scale reading.

Measuring Range: 0-99.99 opacity in”

Measurement Chamber: Effective Length 0.430 m ± 0.005 m.

Light Source: 12 V -5 W Halogen Bulb.

Detector: Selenium Photocell dia 45mm.

Size: 570 mm X 500 mm X 1250 mm

Weight: 20 kg.
Exhaust Gas Analyzer Specifications

Name: Five Gas Emission Analyzer
Model: 5G -10
Manufacturer: Planet Equipment, 1215 North Acacia Drive, Gilbert, Arizona 85233.
www.planet-equipment.com

Specifications:
Measurement Method: NDIR (Non-Dispersive Infrared) for HC, CO, CO\textsubscript{2}.
Electrochemical for NO, O\textsubscript{2}.

Programme
Accuracy
Adherence: EPA ASM ASM/BAR97 OIML Class 0 and OIML Class 1

Gases Measured: Displayed Data Measurement Accuracy
1) HC (Hydrocarbon) 0-30,000 ppm 01 ppm
2) CO (Carbon Monoxide) 0-15 % 0.01%
3) CO\textsubscript{2} (Carbon Dioxide) 0-20 % 0.01 %
4) NOx (Oxides of Nitrogen) 0-5000 ppm 01 ppm
5) O\textsubscript{2} (Oxygen) 0-25% 0.01 %

Size: 26 cm X 19 cm X 9 cm
Weight: 3.1 kg.
Appendix -V

Uncertainty Analysis

The experimental investigations involve the use of different instruments for measurement of different parameters. These instruments or equipment are made by different manufacturers using different technologies. The accuracy of measurement and their performance may vary depending on the operating and experimental environment. Hence the uncertainty occurs due to fixed or random errors. The uncertainty in the measured parameter can be estimated based on analytical methods. Thus the uncertainty can be estimated using Gaussian distribution method with confidence limits of $2 \sigma$.

Uncertainty of any measured parameter
\[
\Delta x_i = \frac{2\sigma_i}{\bar{x}_i} \times 100
\]  

(1)

Number of readings were obtained through experimentation to obtain mean ($\bar{x}_i$) and standard deviation($\sigma_i$) of the measured parameters.

The uncertainties in computed parameters are evaluated by using following expression.

Let $R$ be the computed quantity from “n” independent measured parameters $x_1, x_2, x_3, \ldots, x_n$.

Thus $R = R(x_1, x_2, x_3, \ldots, x_n)$  

(2)

Let uncertainty parameters for the measured parameters be  
\[ x_1 \pm \Delta x_1, \ x_2 \pm \Delta x_2, \ x_3 \pm \Delta x_3, \ldots, \ x_n \pm \Delta x_n \]

and the uncertainty for the computed value be  
\[ R \pm \Delta R \]

In order to get realistic error limits for the computed quantity the principle of root-sum square method is used and the magnitude of the error is given by

\[
\Delta R = \sqrt{\left(\frac{\partial R}{\partial x_1} \Delta x_1 \right)^2 + \left(\frac{\partial R}{\partial x_2} \Delta x_2 \right)^2 + \left(\frac{\partial R}{\partial x_3} \Delta x_3 \right)^2 + \cdots + \left(\frac{\partial R}{\partial x_n} \Delta x_n \right)^2}
\]  

(3)
Using the above equation for a given operating condition the uncertainties are computed for the measured quantities are listed below:

N = Speed ± 1.0 %
W = Load ± 0.5 %
BP = Brake Power ± 0.5 %
BSFC = Brake specific fuel consumption ± 1.4 %
EGT = Exhaust gas temperature ± 0.2 %
BTE = Brake thermal efficiency ± 1.1 %
CO = carbon Monoxide ± 0.2 %
HC = Hydro carbon ± 0.2 %
NOx = Oxides of Nitrogen ± 0.3 %
SO = Smoke opacity ± 1.1 %
PP = Pressure pickup ± 1.0 %

The percentage of uncertainty of the experiment is

\[
\sqrt{(N)^2 + (BP)^2 + (BSFC)^2 + (EGT)^2 + (BTE)^2 + (CO)^2 + (HC)^2 + (NO_x)^2 + (SO)^2 + (PP)^2}
\]

= \sqrt{1.0^2 + 0.5^2 + 1.4^2 + 0.4^2 + 1.1^2 + 0.2^2 + 0.2^2 + 0.3^2 + 1.1^2 + 1.0^2}

= 2.61 %