11. APPENDICES

11.1 Appendix A: Generator Design

11.1.1 Appendix A1: Generator PVC Properties

Table A1: uPVC Properties [24]

Material:	SABS Class 16 uPVC
Max. Operating Pressure:	1.6 MPa
Specific Gravity:	1.45 $g.cm^{-3}$
Maximum Service Temperature:	65 °C
Tensile Strength (Yield):	55 MPa
Impact Resistance:	No Break
Hardness Ball Indentation:	120 $N.mm^{-2}$
Co-efficient of Thermal Expansion:	70 $x10^{-6}$ mm/mm.K
Surface Resistivity:	10^{13} $\Omega.mm^{-2}$
Thermoforming Temperature:	120 – 150 °C

11.1.2 Appendix A2: Thread Specifications

Table A2: Thread Specifications [27]

		Coarse Threads—UNC			Fine Threads—UNF		
Size	Major Diameter d (in.)	Threads per Inch	Minor Diameter of External Thread d_r (in.)	Tensile Stress Area A_t (in.^{2})	Threads per Inch	Minor Diameter of External Thread d_r (in.)	Tensile Stress Area A_t (in.^{2})
0(.060)	0.0600	—	—	—	80	0.0447	0.00180
1(.073)	0.0730	64	0.0538	0.00263	72	0.0560	0.00278
2(.086)	0.0860	56	0.0641	0.00370	64	0.0668	0.00394
3(.099)	0.0990	48	0.0734	0.00487	56	0.0771	0.00523
4(.112)	0.1120	40	0.0813	0.00604	48	0.0864	0.00661
5(.125)	0.1250	40	0.0943	0.00796	44	0.0971	0.00830
6(.138)	0.1380	32	0.0997	0.00909	40	0.1073	0.01015
8(.164)	0.1640	32	0.1257	0.0140	36	0.1299	0.01474
10(.190)	0.1900	24	0.1389	0.0175	32	0.1517	0.0200
12(.216)	0.2160	24	0.1649	0.0242	28	0.1722	0.0258
$\frac{1}{4}$	0.2500	20	0.1887	0.0318	28	0.2062	0.0364
$\frac{5}{16}$	0.3125	18	0.2443	0.0524	24	0.2614	0.0580
$\frac{3}{8}$	0.3750	16	0.2983	0.0775	24	0.3239	0.0878
$\frac{7}{16}$	0.4375	14	0.3499	0.1063	20	0.3762	0.1187
$\frac{1}{2}$	0.5000	13	0.4056	0.1419	20	0.4387	0.1599
$\frac{9}{16}$	0.5625	12	0.4603	0.182	18	0.4943	0.203
$\frac{5}{8}$	0.6250	11	0.5135	0.226	18	0.5568	0.256
$\frac{3}{4}$	0.7500	10	0.6273	0.334	16	0.6733	0.373
$\frac{7}{8}$	0.8750	9	0.7387	0.462	14	0.7874	0.509
1	1.0000	8	0.8466	0.606	12	0.8978	0.663
$1\frac{1}{8}$	1.1250	7	0.9497	0.763	12	1.0228	0.856
$1\frac{1}{4}$	1.2500	7	1.0747	0.969	12	1.1478	1.073
$1\frac{3}{8}$	1.3750	6	1.1705	1.155	12	1.2728	1.315
$1\frac{1}{2}$	1.5000	6	1.2955	1.405	12	1.3978	1.581
$1\frac{3}{4}$	1.7500	5	1.5046	1.90			
2	2.0000	$4\frac{1}{2}$	1.7274	2.50			
$2\frac{1}{4}$	2.2500	$4\frac{1}{2}$	1.9774	3.25			
$2\frac{1}{2}$	2.5000	4	2.1933	4.00			
$2\frac{3}{4}$	2.7500	4	2.4433	4.93			
3	3.0000	4	2.6933	5.97			
$3\frac{1}{4}$	3.2500	4	2.9433	7.10			
$3\frac{1}{2}$	3.5000	4	3.1933	8.33			
$3\frac{3}{4}$	3.7500	4	3.4433	9.66			
4	4.0000	4	3.6933	11.08			

Note: See ANSI standard B1.1-1974 for full details. Unified threads are specified as "$\frac{1}{2}$ in.–13UNC," "1 in.–12UNF."

11.2 Appendix B: Design Drawings

11.3 Appendix C: Preliminary Experimental Data

11.3.1 Appendix C1: Temperature Test Results

Table C1: Temperature Test Results

Time	Mass of Water Loss	Temp	Rate of Water Loss	Molecular Rate of Water Loss	Molecular Rate of H_2 Produced	Mass of H_2 Produced	Volume of H_2 Produced
[s]	[g]	[deg C]	[g/s]	[mol/s]	[mol/s]	[g/s]	[m^3/s]
55	0.2	22.00	0.003636	2.019E-04	2.019E-04	0.000407	0.00453
900	5.1	36.40	0.005667	3.146E-04	3.146E-04	0.000634	0.00705
900	5.2	37.90	0.005778	3.207E-04	3.207E-04	0.000647	0.00719
900	9.9	48.80	0.011000	6.106E-04	6.106E-04	0.001231	0.01369
900	14	55.00	0.015556	8.635E-04	8.635E-04	0.001741	0.01936

11.3.2 Appendix C2: Sample Calculation [31]

- **Atomic Mass of Water**

$$
\begin{aligned}
A_{,water} &= A_H + A_O \\
&= (2)(1.008) + (15.9994) \\
&= 18.01
\end{aligned}
\qquad \text{(C.1)}
$$

- **Rate of Water Loss**

$$
\begin{aligned}
\dot{m}_{water} &= \frac{m_{water}}{t} \\
&= \frac{14}{900} \\
&= 0.015556 g.s^{-1}
\end{aligned}
\qquad \text{(C.2)}
$$

- **Molecular Loss of Water**

$$
\begin{aligned}
\dot{M}_{water} &= \frac{\dot{m}_{water}}{A_{water}} \\
&= \frac{0.015556}{18.01} \\
&= 8.635 x 10^{-4} mol.s^{-1}
\end{aligned}
\qquad \text{(C.3)}
$$

- **Molecular Weight of Hydrogen**

From, the balanced equation for the dissociation of water into hydrogen and oxygen, it can be seen that for every mole of water there is one mole of hydrogen produced.

$$2H_2O = 2H_2 + O_2$$

Therefore, the number of moles of hydrogen produced is equal to the number of moles of water used up.

$$\dot{M}_{hydrogen} = 8.635x10^{-4}\, g.s^{-1}$$

- **Mass of Hydrogen Produced**

$$\dot{m}_{hydrogen} = \left(\dot{M}_{hydrogen}\right)\left(A_{hydrogen}\right) \quad \text{(C.5)}$$

$$= \left(8.635x10^{-4}\right)(2)(1.008)$$

$$= 0.001741 g.s^{-1}$$

- **Volume of Hydrogen Produced**

$$V = \frac{m}{\rho} \quad \text{(C.6)}$$

$$= \frac{0.001741}{0.0000899}$$

$$= 0.01936 m^3$$

11.3.3 Appendix C3: Frequency Test Results

Table C2: Frequency Test Results

Time	Mass of Water Loss	Frequency	Rate of Water Loss	Molecular Rate of Water Loss	Molecular Rate of H_2 Produced	Mass of H_2 Produced	Volume of H_2 Produced
[s]	[g]	[kHz]	[g/s]	[mol/s]	[mol/s]	[g/s]	[m^3/s]
1800	2.3	16.67	0.001278	7.093E-05	7.09285E-05	0.000143	0.00159
1800	3.4	20.00	0.001889	1.049E-04	0.000104851	0.000211	0.00235
1800	2.8	20.00	0.001556	8.635E-05	8.63478E-05	0.000174	0.00194
1800	3.3	20.83	0.001833	1.018E-04	0.000101767	0.000205	0.00228
1800	2.9	22.73	0.001611	8.943E-05	8.94316E-05	0.000180	0.00201
1800	2.7	25.00	0.001500	8.326E-05	8.32639E-05	0.000168	0.00187
1800	3.7	50.00	0.002056	1.141E-04	0.000114102	0.000230	0.00256
1800	3.6	62.50	0.002000	1.110E-04	0.000111019	0.000224	0.00249
1800	3.3	66.67	0.001833	1.018E-04	0.000101767	0.000205	0.00228
1800	3.6	100.00	0.002000	1.110E-04	0.000111019	0.000224	0.00249

11.4 Appendix D: Dynamometer Calibration

Table D1: Dynamometer Calibration Data

Mass [lb]	Mass [kg]	Load [N]	Torque [Nm]	Voltage [V]
1.37	0.62	6.07	2.22	3.28
1.62	0.73	7.21	2.63	3.29
1.87	0.85	8.32	3.04	3.3
2.12	0.96	9.43	3.44	3.31
2.62	1.19	11.66	4.26	3.34
3.62	1.64	16.11	5.88	3.38
5.82	2.64	25.90	9.45	3.47
8.02	3.64	35.69	13.03	3.57
8.27	3.75	36.80	13.43	3.58

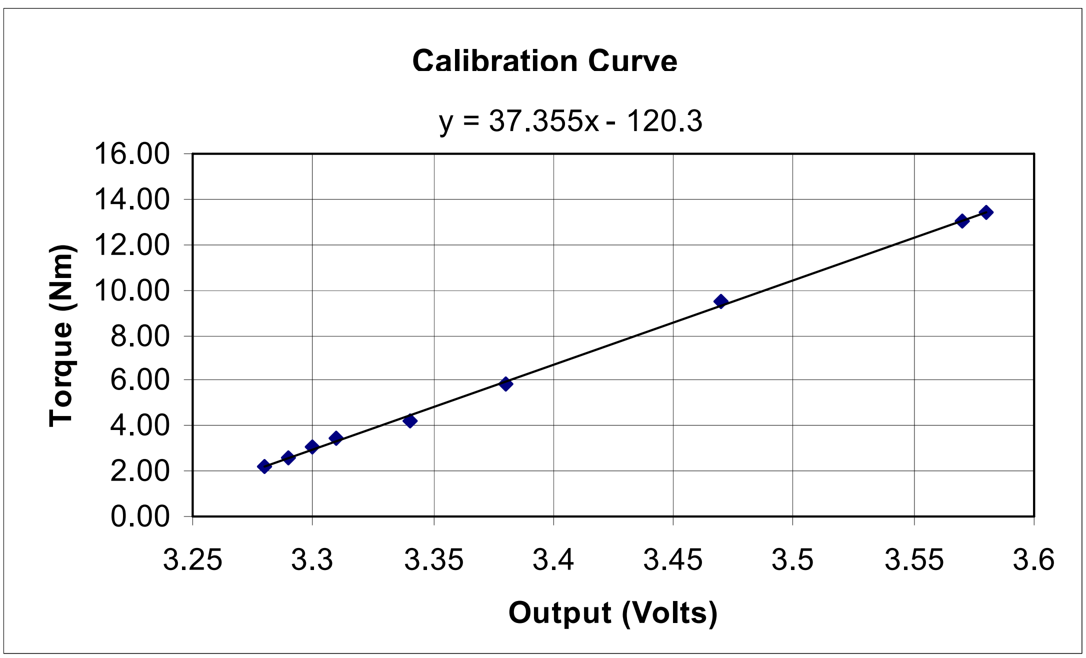

Figure D1: Dynamometer Calibration Curve

11.5 Appendix E: Gas Analyser Procedure

The procedures to follow are for the Signal Series III Analyser. For each test session these procedures have to be performed to ensure good working order of the analyser.

11.5.1 Appendix E1: Start up Procedure

1. Switch on the main power supply at the wall plug. The pumps will start up, the oven lights will burn and the fans will turn on.
2. Switch on all the analyser units (CO, CO_2, NO_X and cooler/dryer). The switches to these analysers are on the front panels of each unit.
3. All the display panels (LCD) will now be lit up and go into standby mode.
4. A Status warning will show on all the LCD displays of the analyser units.
5. Press the STATUS button and then press the PAGE DOWN button twice. Do this for all the analyzer units.
6. The window being displayed at this stage on all of the units should be the “Health Check Window”, which gives the operating status of the analyzer by listing all the operating variables. A flashing variable alerts the user to a problem with that specific variable. Upon start up, usually temperature, pressure and/or the flow variables will be flashing.
7. Allow all units to stand as they are for about 45 minutes to an hour, to allow the oven and converter temperatures in the NO_X analyser to reach the operating temperatures required. The variables will stop flashing to indicate operating status.

11.5.2 Appendix E2: Analyser Requirements and Gas Cylinder Contents

Table E1: Gas Cylinder Contents

Analyser	Cylinder Label	Cylinder Contents	Description
NO_X	Zero	99.9 % Nitrogen	Large
	Span	3030 ppm NO in N_2	Large
CO	Zero	99.9 % Nitrogen	Large
	Span	8.0 % in air	Large
CO_2	Zero	99.9 % Nitrogen	Large
	Span	15.6 % CO_2 in air	Large

11.5.3 Appendix E3: Calibration Procedure

1. Once the NO_X oven and converter temperatures have reached their required levels (i.e. no longer flashing), then the next phase can begin. Double check to see that the above two temperature variables on the LCD panels are not flashing.
2. Now press the ESC (Escape) button on all the analysers.
3. Press the SAMPLE button (the button below the LCD screen aligned with SAMP on the screen) on all the analysers. This will change the analyser units from STANDBY to SAMPLE mode.
4. Open the NO_X ZERO (nitrogen) gas cylinder. **NB:** Do not turn the regulator dials. All the cylinders have regulators that have been pre-set because of the flows and pressures required by each analyser. The main cylinder valve is the one to be opened.
5. Open the laboratory's supply of compressed air by turning the valve halfway (45^O). The compressed air passes through three filters, namely particulate, water and oil.

6. The CO_2, CO and NO_X analysers should now be in SAMPLE mode without any STATUS warnings.
7. When calibrating, each analyser is calibrated separately, first starting with the NO_X, followed by the CO_2 and lastly the CO analyser.
8. Open a single SPAN cylinder corresponding to the analyser to be calibrated. Now press CAL button (the button below the LCD screen aligned with CAL on the screen) on the analyser, and wait for the calibration process to complete before moving onto the next analyser.
9. The calibration process on the analyser first processes ZERO calibration and then proceeds to SPAN calibration, the analyser then reads "SAMPLE SETTLING" on the LCD screen, after which it returns to SAMPLE mode. Once this is done, the calibration process is complete.
10. If a STATUS WARNING is given after the calibration, one or some of the variables have not reached their required status for calibration. Proceed to the "Health Check" window and establish which variables are flashing.
11. Most often it is the gas flow variables that flash, this means insufficient gas is flowing through the analyser. **NB: Adjust the regulator knobs on the gas cylinder until the variable stops flashing, do this carefully**. *This is the only time that the regulator knobs should be turned otherwise not.* Re-calibrate the analyser.
12. After calibration of a single analyser the SPAN cylinder should be shut. Only the ZERO and FUEL cylinders remain open throughout until testing is complete.
13. Now check to see that the calibration process was successful. This is done by pressing the STATUS button, and then the PAGE DOWN button once. The effective range should lie between –100% and +100% for all the analyser units.
14. *Note: If the STATUS WARNING appears, due to N_2 gas flow on the CO or CO_2 while calibration occurs is because N_2 is used by both CO and CO_2 at the same time, it should stop flashing after calibration, if it does not the regulator knob should be adjusted until it stops on both analysers.*
15. If all the preceding procedures have been completed, refer to the table which follows to check that all the variables on the 'Health Check Window' are within the given ranges.

11.5.4 Appendix E4: Variable Ranges For Each Analyser

If the variable values are not within range, the analyser will give a “STATUS WARNING” error message.

Table E2 - Variable Ranges for CO_2 Analyser

Analyser	Variable	Normal Reading	Upper Limit Reading	Lower Limit Reading
CO_2 7000 M	Amb. Temp.	40 °C	58 °C	0 °C
	Sens Status	GOOD	FAULT [1]	
	P. S. Status	GOOD	FAULT [1]	
	N_2 Pressure	0.14 bar	Check footnote # **2**	
	Gas Flow	0.7 l/m	1.0 l/m	0 l/m
	Measure 147.9 POH			

Table E3 - Variable Ranges for CO Analyser

Analyser	Variable	Normal Reading	Upper Limit Reading	Lower Limit Reading
CO 7000 M	Amb. Temp.	38 °C	58 °C	0 °C
	Sens Status	GOOD	FAULT [1]	
	P. S. Status	GOOD	FAULT [1]	
	N_2 Pressure	0.18 bar	Check footnote # **2**	
	Gas Flow	0.5 l/m	1.0 l/m	0 l/m

Table E4 - Variable Ranges for NO_x Analyser

Analyser	Variable	Normal Reading	Upper Limit Reading	Lower Limit Reading
NO_X 4000 VM	Oven Temp.	195 ^oC	205 ^oC	175 ^oC
	Conv. Temp.	383 ^oC	400 ^oC [4]	360 ^oC
	Amb. Temp.	39 ^oC	60 ^oC	0 ^oC
	P. S. Status	GOOD	FAULT [1]	
	H. T. Status	GOOD	FAULT [1]	
	O_3 Pressure	1.06 bar	1.25 bar [5]	0.75 bar
	Vac. Pressure	0.05 bar	0.05 bar	0.01 bar
	Gas Flow	1.9 l/m	5.0 l/m	0.5 l/m

NOTE: IN THE ABOVE TABLES, THE NORMAL READING FOR ALL THE VARIABLES INDICATES PERFECT OPERATION, HOWEVER SHOULD THE VARIABLE READINGS VARY SLIGHTLY BUT ARE STILL WITHIN RANGE; NO ERROR MESSAGES WILL APPEAR.

11.5.5 Appendix E5: Notes

1. The analyser will give a “FAULT” warning, refer to the manual for help or contact a Signal technician.
2. The user manuals do not specify upper and lower limits. If a STATUS WARNING appears on the LCD display then it means insufficient N_2 is flowing through the analyser. Page down to the “Health Check Window” and the N_2 gas flow variable will be flashing. Adjust the regulator on the N_2 gas cylinder until the N_2 variable on the “Health Check Window” stops flashing, check that this is achieved on both the CO and CO_2 analyser.

3. Flashing of this variable will commence, which indicates the temperature is too high or too low.
4. This value is not given in the operating manuals.
5. The optimum O_3 pressure is 1.00 bar and 1.25 bar is an estimated Upper limit.

11.5.6 Appendix E6: Problems With Calibration

Should any problems occur with the calibration of the analyser, a CAL WARNING error message will appear on the LCD screen. The following procedure should be used.

- On the front panel of the analyser, with the error message, press the STATUS button and then the PAGE DOWN button once. The effective range for any of the variables should lie between –100% and +100%. The error message will have appeared if one or more of the variables lie outside the –100% and +100% limits. Find out which of these is causing the fault.
- Check to see that the SPAN/ZERO main valve on the cylinder for that variable is open. If it is closed, open it and recalibrate.
- If the valve is open already, then place the analyser in the correct the correct mode to read the value of the cylinder contents. To get the analyser in this mode, while in the sample mode screen, press the PAGE DOWN button once and notice on the LCD screen, the SPAN and ZERO will appear on the bottom of the screen.
- If the SPAN is giving the problem, press SPAN and wait for the analyser to read the contents of the SPAN of the cylinder. Once this value has been established, adjust the potentiometer on the inside of the analyser front panel (see user manual for location).
- By adjusting the potentiometer, the value being read by the analyser can be adjusted to read the value of the cylinder.
- Once this has been done, close the front panel, place the analyser back into SAMPLE mode and recalibrate.

11.5.7 Appendix E7: Shut Down

1. Once testing is completed for the day, remove the heated line from the exhaust connection.
2. Allow the analyser to “air out” for 30 minutes to an hour.
3. Press STOP on the front panels of all the analyser units. The analyser units will now begin to purge themselves (120 seconds).
4. When this is complete, the units will all be in STANDBY mode.
5. Now close all the cylinder main valves and do not tamper with the regulator valves.
6. Turn off the air supply.
7. Switch off the front panel power switches.
8. Switch off the wall plug power.

11.6 Appendix F: Emissions Data Acquisition Procedure

Once the PC has been started up in Windows and the Analyser unit has been calibrated then the software program may be set up to capture the test data. The program used is Signal and this measures the emissions of the engine in a graphical mode by calculating the average concentration of the emissions and plotting the results as the test is being performed. If anything were to go wrong during a test then one would immediately notice this by the change in pattern of the graphs being plotted. The emissions measured are the Nitric Oxide (NO_X), Carbon monoxide (CO) and Carbon dioxide (CO_2) emissions. The following procedure briefly outlines the steps involved whilst performing tests with emissions.

1. Double click on the **Signal** icon (torch flame picture) to open the **Signal Exhaust Analyser Software** operating window.
2. Click the **Test** button on the menu bar scroll to click the **Start New Test** button. This will then open the **Start New Test Information Window.**

3. Here the test name is entered as before and the operator can select the number of data points. For this research project either 50 or 100 points were chosen depending on the time available for each test.
4. The **Reading Interval** was set at every **1 second.**
5. Clicking the icon with the little folders on it can choose the directory, to which the data is to be saved. Here select the path C:\SignalProgam\Signaldata\{Folder}. The entry {Folder} is to be replaced with whichever folder the data is to be stored in. This is usually the date of the test and the test number, eg. 2702, which reads 27th of November and test number two for that day.
6. The operating window shows all concentrations graphically and numerically as the test is being run.
7. For each new test, the new test name needs to be re-entered in order to be stored for further use.
8. The captured data may be viewed in *Notepad* at a later stage for further use.

11.7 Appendix G: Raw Data

Table G1: Petrol Data at ½ Throttle

THROTTLE:	½	FUEL:	Petrol	
Engine Speed		**NO_x**	**CO**	**CO_2**
[rpm]		**[ppm]**	**[ppm]**	**[ppm]**
2000		781	51040	72232
		768	53914	-
		701	-	-
		676	-	-
		605	-	-
	Average:	**706**	**52477**	**72232**
1940		467	62230	82080
		510	63820	81870
		537	62080	81610
		521	62560	-
		485	63249	-
	Average:	**504**	**62788**	**81853**
1840		482	66302	82002
		497	66440	81827
		473	-	81410
		476	-	81352
		499	-	81000
	Average:	**485**	**66371**	**81518**
1480		3005	30939	89415
		2039	33005	89170
		2462	29919	89075
		3108	29741	88930
	Average:	**2654**	**30901**	**89147**

Table G2: Hydrogen Data at ½ Throttle

THROTTLE:	½	FUEL:	Petrol & Hydrogen	
Engine Speed		NO_x	CO	CO_2
[rpm]		[ppm]	[ppm]	[ppm]
2000		887	40682	83500
		984	39665	83815
		968	40143	83665
		835	41193	84360
		860	-	85009
		-	-	80915
		-	-	83365
		-	-	85415
		-	-	87040
	Average:	**907**	**40420**	**84120**
1860		706	50315	86255
		727	52120	87925
		728	51655	88260
		721	51800	88770
		-	-	89300
	Average:	**720**	**51472**	**88102**
1740		683	55925	90405
		772	57355	90820
		716	56410	91060
		702	59120	91100
		718	59220	91075
	Average:	**718**	**57606**	**90892**
1280		1551	38715	90970
		1468	35417	90835
		-	38321	-
		-	41767	-
	Average:	**1509**	**38555**	**90902**

Table G3: Petrol Data at ⅔ Throttle

THROTTLE:	⅔	FUEL:	Petrol	
Engine Speed		**NO_x**	**CO**	**CO_2**
[rpm]		**[ppm]**	**[ppm]**	**[ppm]**
2360		681	54805	86057
		767	54269	85690
		687	56102	85600
		750	-	80585
		870	-	-
		731	-	-
		734	-	-
		730	-	-
		952	-	-
	Average:	**767**	**55059**	**84483**
2220		532	71555	83445
		502	72385	85312
		497	73305	86535
		502	-	87682
		520	-	88477
	Average:	**511**	**72415**	**86290**
1960		504	75372	89122
		502	79307	89157
		489	77972	88692
		487	78472	87957
		487	79077	87135
	Average:	**494**	**78040**	**88412**
1660		2723	28745	85535
		2537	29608	85085
		2369	30361	84545
		2799	27187	-
		2478	-	-
	Average:	**2581**	**28975**	**85055**

It should be noted that Table G4 is somewhat different from the previous Tables in that each emission has its own corresponding engine speed. This was due to the difficulty in obtaining the exact engine speed when the hydrogen tests were repeated at two-thirds throttle. However, while these engine speeds are different to those in Table 8.4, the specific emissions and plotted results were determined using the true data in Table G4 below.

Table G4: Hydrogen Data at ⅔ Throttle

	THROTTLE:	⅔	FUEL:	Petrol & Hydrogen		
	NO_x		CO		CO_2	
	Emissions [ppm]	Speed [rpm]	Emissions [ppm]	Speed [rpm]	Emissions [ppm]	Speed [rpm]
	583	1880	58020	1880	91044	1880
	671		58120		90625	
	677		57370		90437	
			56630		90272	
Average:	**644**		**57535**		**90595**	
	635	1920	46574	1920	91390	1920
	605		47402		91292	
	612		47726		91500	
	615				91402	
Average:	**616**		**47234**		**91396**	
	855	2080	45768	1980	91366	1980
	934		40079		92218	
			40805		92062	
			43104		91722	
			48898			
			46944			
Average:	**895**		**44266**		**91842**	
	966	2120	10147	2120	82714	2080
	983		9916			
			9060			
Average:	**974.5**		**9708**		**82714**	

11.8 Appendix H: *EES* Source Code

```
{VARIABLES}
{v=dynamometer reading}
{p=power}
{T=torque}
{deltap = change in pressure}
{s=time taken to consume 50ml fuel}
{n=rpm}
{bmep=brake mean effective pressure}
{Vd=displacement volume}
{Nc=cylinder factor}
{lb=calibration mass in pounds}
{m=mass in kilograms}
{F=load on dynamometer}
{x=torque arm distance}
{Tcal = calibration torque}
{vcal= calibration voltage}
{nox=nitrogen oxides}
{co=carbon monoxide}
{co2=carbon dioxide}
{snox=specific nox}
{sco=specific co}
{sco2=specific co2}
{AFa=Actual Air/Fuel Ratio}
{FAa=Actual Fuel/Air Ratio}
{FAs=Stoichiometric Fuel/Air Ratio}
{eq=equivalence ratio}

{CALIBRATION}
m=0.45359*lb
F=m*9.81
Tcal=F*x
x=0.365

{RESULTS}
T=37.3468*v-120.272
p=2*pi*n*T/60
bmep*1000=(p*Nc)/(Vd*n/60)
Vd=pi*((bore/2)^2)*stroke
bore=0.082
stroke=0.064
Nc=0.5
snox=nox/p
sco=co/p
sco2=co2/p
1/FAa=AFa
eq=FAa/FAs
1/FAs=AFs
 AFs=14.7
```

11.9 Appendix I: Curve Fit Equations

11.9.1 Appendix I1: Torque

½P: $-22.742 + 0.0034157*n – 0.000104031*n^2$

½H: $1.40469 + 0.0072154*n – 0.00000285301*n^2$

⅔P: $-7.24869 + 0.0132859*n – 0.00000362076*n^2$

⅔H: $-186989 + 0.028862*n – 0.0000849106*n^2$

Where “n” represents engine speed.

11.9.2 Appendix I2: BMEP

½P: $-211.311 + 0.317392*n – 0.0000966669*n^2$

½H: $13.0681 + 0.0670515*n – 0.0000265138*n^2$

⅔P: $-67.2642 + 0.123381*n – 0.0000336283*n^2$

⅔H: $-180.518 + 0.275049*n – 0.0000806293*n^2$

Where “n” represents engine speed.

11.9.3 Appendix I3: NO_x

½P: $50513.8 – 53.476*n + 0.0142832*n^2$

½H: $11464.8 – 12.2131*n + 0.00346544*n^2$

⅔P: $47016.9 – 43.8945*n + 0.0103082*n^2$

⅔H: $24632 – 25.4099*n + 0.006725*n^2$

Where “n” represents engine speed.

11.9.4 Appendix I4: CO

½P: $-1.06416x10^6 + 1253.94*n – 0.34734*n^2$

½H: $-342315 + 486.528*n – 0.147621*n^2$

⅔P: $-1.24563x10^6 + 1282.82*n – 0.31015*n^2$

⅔H: $1141060 + 1369.51*n – 0.3898.89*n^2$

Where “n” represents engine speed.

11.9.5 Appendix I5: CO_2

½P: $-99067.5 + 242.115*n – 0.0777184*n^2$

½H: $13297.1 + 105.523*n – 0.0350689*n^2$

⅔P: $-23877.7 + 122.689*n – 0.0283297*n^2$

⅔H: $1.76482x10^6 + 1912.75*n – 0.492536*n^2$

Where “n” represents engine speed.

11.9.6 Appendix I6: Specific NO_x

½P: $68.778 – 0.00732004*n + 0.0000196159*n^2$

½H: $57.409 – 0.0536221*n + 0.0000125718*n^2$

⅔P: $15.7386 – 0.0169289*n + 0.00000477244*n^2$

⅔H: $32.6927 – 0.0338755*n + 0.0000089327*n^2$

Where “n” represents engine speed.

11.9.7 Appendix I7: Specific CO

½P: $-789.187 + 0.878974*n – 0.000238328*n^2$

½H: $-1085.09 + 1.12876*n – 0.000273508*n^2$

⅔P: $-240.199 + 0.373736*n –0.000115944*n^2$

⅔H: $-1154.85 + 1.35937*n – 0.00038195*n^2$

Where “n” represents engine speed.

11.9.8 Appendix I8: Specific CO_2

½P: $6914.67 – 11.3638*n + 0.00627679*n^2 – 0.0000115073*n^3$

½H: $802.103 + 1.52221*n – 0.000835727*n^2 + 1.48497*n^3$

⅔P: $1717.07 – 2.85342*n + 0.00166087n^2 – 3.20474x10^{-7}*n^3$

⅔H: $1054.45 + 1.15118*n – 0.000290613*n^2$

Where “n” represents engine speed.

11.9.9 Appendix I9: Equivalence Ratio

½P: 81.848 + 0.130152*n – 0.0000667182*n^2 + 1.12470x10^{-8}*n^3

½H: 7.61349 – 0.0107492*n + 5.9269x10^{-6}*n^2 – 1.09389x10^{-9}*n^3

⅔P: 110.944 – 0.12792*n + 0.000496946*n^2 – 6.50001x10^{-9}*n^3

⅔H: 5.34536 – 0.00321615*n + 6.07641x10^{-7}*n^2

Where "n" represents engine speed.

11.10 Appendix J: Final Test Results – Sample Calculation

Using the data for two-thirds petrol:

11.10.1 Appendix J1: Torque

From the calibration equation:

$$
\begin{aligned}
T &= -120.30 + 37.355V \\
&= -120.30 + 37.355(3.325) \\
&= 3.906 Nm
\end{aligned}
$$

11.10.2 Appendix J2: Power

The engine power was then calculated using equation 8.2 [32]:

$$P = \frac{2\pi NT}{60}$$
$$= \frac{2\pi(2360)(3.906)}{60}$$
$$= 965.323W$$

11.10.3 Appendix J3: BMEP

$$BMEP = \frac{pN_c}{V_d N}$$
$$= \frac{(965.323)(0.5)}{(0.000337985)\left(2360/60\right)}$$

$$= 36.3kPa$$

11.10.4 Appendix J4: Specific NO_x

$$sNO_x = \frac{NO_x}{P}$$
$$= \frac{767}{965.323}$$
$$= 0.7645\,ppm.W^{-1}$$

11.10.5 Appendix J5: Specific CO

$$sCO = \frac{CO}{P}$$
$$= \frac{55059}{965.323}$$
$$= 57.04\, ppm.W^{-1}$$

11.10.6 Appendix J6: Specific CO_2

$$sCO_2 = \frac{CO_2}{P}$$
$$= \frac{84483}{965.323}$$
$$= 87.52\, ppm.W^{-1}$$