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Faculty of Mechanical Engineering

UTILIZATION OF ELECTRICAL HEATER UNIT AND SECONDARY AIR INJECTION INTO UNDERBODY CATALYST FOR REDUCTION OF EXHAUST GAS EMISSION

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Bachelor of Mechanical Engineering

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UTILIZATION OF ELECTRICAL HEATER UNIT AND SECONDARY AIR INJECTION INTO UNDERBODY CATALYST FOR REDUCTION OF EXHAUST GAS EMISSION

RAJA NAZIRUL MUBIN BIN RAJA ISMAIL

A thesis submitted

in fulfilment of the requirement of the degree of Bachelor in Mechanical Engineering

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2018

DECLARATION

"I hereby declare that the work in this whole report is my own except for the summaries and quotations which have been duly acknowledged"

Signature : ……………………………………….

Author : Raja Nazirul Mubin Bin Raja Ismail

Date : ……………………………………….

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SUPERVISOR APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of Bachelor of Mechanical Engineering (with Honours).

Signature : ....

Supervisor Name : Associate Professor Dr. Noreffendy bin Tamaldin

Date : ....

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DEDICATION

To my beloved family

To a very supportive and respected supervisor

To UTeM staff

&

To my friends

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ABSTRACT

Exhaust gas emission plays an important role in maintaining the index of clean air and human health. It is important to reduce the emission of these harmful gases such as hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxide (NOx). In that matter, it is believed that most of these gases comes from emission of automobile exhausts and factories as a product of engine combustion. The implant of three ways catalyst somewhat helps in reducing toxic gases emission by converting them into less toxic gas such as nitrogen gas (N_2), carbon dioxide (CO_2) and water (H_2O) droplet. The catalytic converter takes into effect once it reaches the light-off temperature around 450K. As it takes sometimes before the catalytic converter to reaches its light-off temperature for effective conversion of toxic gases, a few alternatives had been made including bringing catalytic converter closer to the exhaust manifold so that it can exploit hot gas emitted from the engine, installation of secondary air system to enrich oxygen gas, O_2 content for facilitating HC burning and the use of electrically heated element (EHC) to speed up catalyst activation time. The use of EHC to reduce the time taken for the catalytic converter somehow seems one of the best alternatives as it can supply an instant heat to the catalyst for activation before the work changes to the heat supply by the exhaust gas temperature emitted from the engine combustion. However, placing catalyst further from the combustion chamber outlet and the blow of air from secondary air injection system had reduce the exhaust gas temperature and causing a longer the light-off

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time thus reduce the heat received by the catalyst for catalyst activation. Further optimization is needed to improve the efficiency of EHC in term of time and temperature so that the exhaust emission meets the current regulated emission standard.

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ABSTRAK

Pelepasan gas ekzos berperanan penting dalam mengekalkan indeks kebersihan udara dan kesihatan manusia. Harus diketahui bahawa sangat penting untuk mengurangkan pelepasan gas yang berbahaya seperti hidrokarbon (HC), karbon monoksida (CO) dan nitrogen oksida (NOx). Oleh yang demikian, penghasilan gas-gas ini dipercayai berpunca dari ekzos-ekzos kenderaan dan kilang-kilang hasil daripada pembakaran di dalam enjin. Pemasangan 'three ways catalyst' (TWC) dilihat dapat membantu dalam mengurangkan pelepasan gas-gas berbahaya dengan menukarkan gas-gas ini kepada yang kurang berbahaya seperti gas nitrogen (N_2), karbon dioksida (CO_2) dan titisan air (H_2O). 'Catalytic converter' ini hanya akan berfungsi apabila mencapai suhu pengaktifannya sekitar 450K. Memandangkan tempoh masa yang panjang diperlukan sebelum 'catalytic converter' mencapai suhu pengaktifan, beberapa alternatif telah dibuat termasuklah mendekatkan 'catalytic converter' dengan manifold ekzos supaya suhu gas tinggi yang keluar dari enjin hasil dari pembakaran dapat dimanfaatkan, pemasangan sistem udara kedua untuk memperkayakan kandungan gas oksigen,, O_2 bagi kemudahan pembakaran HC dan juga penggunaan 'electricaly heated catalyst' (EHC) untuk mengurangkan jangka masa pengaktifan pemangkin. Penggunaan EHC dilihat sebagai salah satu alternatif terbaik memandangkan EHC dapat membekalkan haba dengan kadar segera kepada pemangkin sebelum tugas memanaskan pemangkin beralih kepada haba yang terhasil dari pembakaran dalam enjin. Walaubagaimanapun, meletakkan

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pemangkin lebih jauh dari salur keluar ruang pembakaran dan tiupan angin oleh sistem suntikan angin kedua telah mengurangkan suhu gas ekzos dan menyebabkan tempoh yang lebih lama diambil untuk pemangkin mencapai suhu pengaktifan. Pengoptimuman selanjutnya diperlukan untuk meningkatkan kadar kecekapan EHC dari segi masa dan suhu supaya pelepasan ekzos memenuhi piawaian pelepasan semasa yang terkawal.

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ACKNOWLEDGEMENT

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I would like to convey a very special appreciation to all the laboratory management and technician especially Mr. Mad Nasir Bin Ngadiman and Mr. Nor Izwan Bin Junoh from Automotive Workshop for their guidance with the fabrication and calibration process throughout the project.

Also, not to forget a very important support from my beloved family on their encouragement, motivation and trust in everything that I do and always be there through my thick and thin. With their support and love it seems possible to go through tough education all these years.

Not to forget my friends and fellow housemate that willing to give examples and help looking for potential source of reference suitable for my research title and teach a proper way to use Microsoft Office Word.

Finally thank you to everyone that involve either directly or indirectly in completing this project. The sacrifice and commitment they give towards completing my Bachelor of Mechanical Engineering programme. Without them this thesis seems impossible to be done.

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LIST OF ABBREVIATIONS

°C	-	Degree Celsius
°F	-	Degree Fahrenheit
GDI	-	Gasoline Direct Injection
EHC	-	Electrical Heated Catalyst
TWC	-	Three Ways Catalyst
CCC	-	Close Couple Catalyst
mK	-	Millikelvin
ms	-	Millisecond
ppm	-	Part per million
HC	-	Hydrocarbon
CO	-	Carbon Monoxide
NOx	-	Nitrogen Oxide
CO_2	-	Carbon Dioxide
N_2	-	Nitrogen gas
O_2	-	Oxygen gas
MΩ	-	Mega Ohm
mV	-	Millivolt
µm	-	Micrometre

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CHAPTER 1

INTRODUCTION

1.1. Background Research

Exhaust gas emission standard had become stricter from day to day thus require a more efficient of harmful gases converter and lower exhaust greenhouse gases emission from vehicle (Chang, Chen, Koo, Rieck, & Blakeman, 2014). USA and Europe legislature future target requirement of exhaust emission reduction by motorcar pushes automobile industry to unstoppably refine the current technology (Pfalzgraf et al., 1995). High technology engine comes with higher fuel efficiency manage to decrease the emission of toxic gases (Chang et al., 2014). This system controlling the gases emission demand needs of catalyst to operate smoothly under cold start and normal condition operation at low temperature (Chang et al., 2014). A good and high-quality exhaust system plays an importance role in producing a high-performance vehicle with low emission. In addition, the performance of the converter during cold starts influenced by exhaust gas transition with electrically heated catalyst, secondary air injections and gasoline burner installation are a few options available alternative to do the work (Powertrain-india, 2016). A high reduction of exhaust gas during cold start of an engine is an indicator of exhaust with high quality emission system.

An electrically heating catalyst is the appliance that was introduce as a heating element that help to reduce exhaust gas reduction during cold start. It helps in burning of hydrocarbon gas to achieve optimum performance.

1.2. Problem Statement

Cold start is one of the main problems occur in nowadays vehicle as the catalytic converter require high temperature before reaching its light-off temperature. The gas emitted from the exhaust consist of hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxide (NOx) which were harmful to the environment as it still not being treated and filtered by catalytic converter that was less functional below its light-off temperature. These untreated gases will cause pollution and not good for human health. There are several designs produced to improve the light-off temperature including by bringing the catalyst closer to the engine so that it can exploit higher exhaust gas temperature.

1.3. Objectives

1. To evaluate E-heater power requirement and recommend suitable placement position along the exhaust system.
2. To design and develop air assisted system to support E-heater application in exhaust.
3. To perform engine performance and emission measurement before and after E-heater air injection system.

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1.4. Scopes

1. Emitec e-heater limited to its power specification up to maximum 10V and 300 Amp
2. The position of air assisted will be limited within the existing exhaust system which provide simple mechanism for air assisted.
3. The engine performance and emission will be performed on a 1.6 litre Proton Persona gasoline engine.

CHAPTER 2

LITERATURE RIVIEW

This section will describe about the previous founding related to the title of studies. The source of references can be from any trusted party including video illustration.

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2.1. THREE WAYS CATALYST (TWC)

TWC is a catalyst used to reduce of Hydrocarbon (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NOx) emitted from exhaust (Chang et al., 2014).

Three way catalyst (TWC), Figure 1, is a device used as a converter of toxic gas produced during engine combustion into less toxic gas (Sankararaj, 2013). The reaction occurs in TWC convert Hydrocarbons (HC), Carbon Monoxide (CO) and Nitrogen Oxide (NOx) into less harm element likes water (H_2O), Nitrogen gas (N_2) and Carbon Dioxide (CO_2) (Sankararaj, 2013).

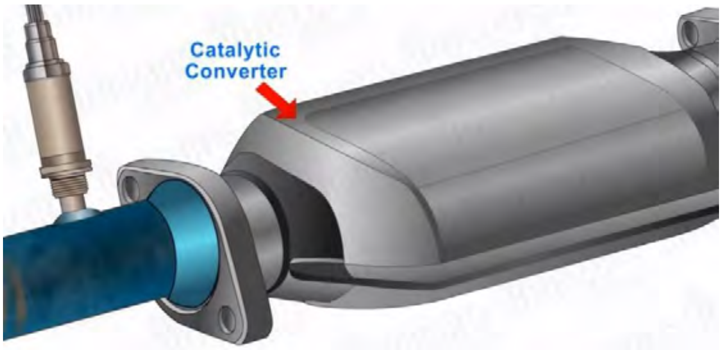

Figure 1 Three Ways Catalytic Converter ("How Car Exhaust System Works," 2013)

TWC consist of two ceramic blocks of micro ducts with platinum (Pt) and rhodium (Rh) is at the first ceramic block called as reduction catalyst followed by platinum (Pt) and palladium (Pd) at the second ceramic block as the oxidation catalyst shown in Figure 2 (Sankararaj, 2013).

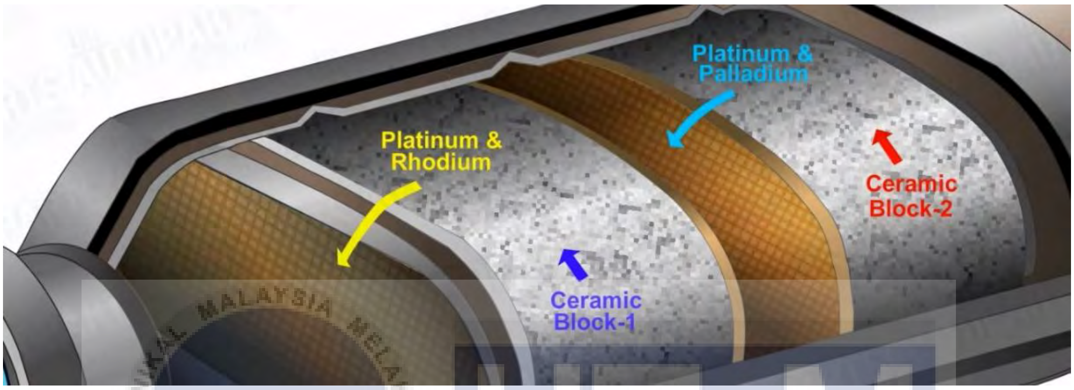

Figure 2 Two Ceramic Blocks ("How Car Exhaust System Works," 2013)

The exhaust gases carrying harmful gas entering the first block causing the catalyst to react with nitrogen oxides that pass through it (Sankararaj, 2013).

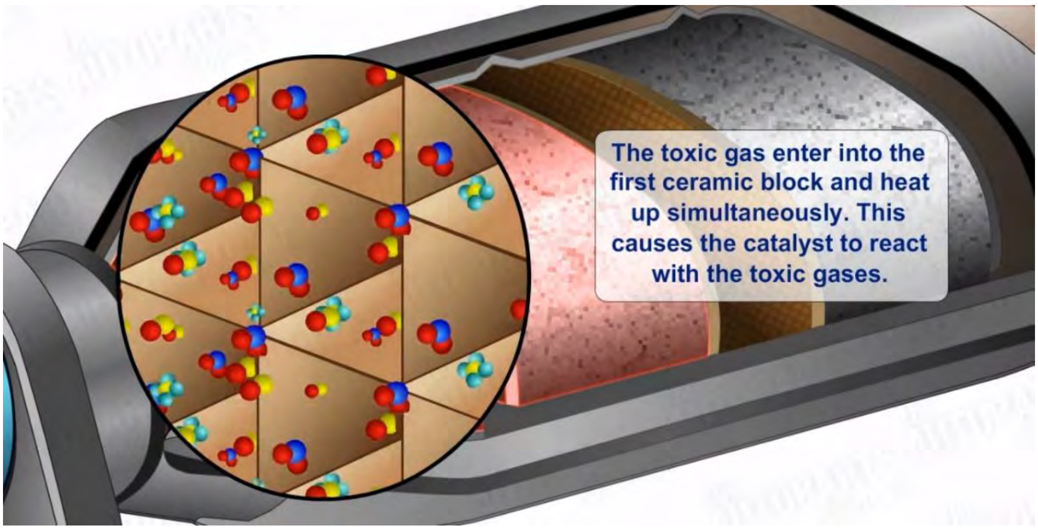

Figure 3 First Block Reaction ("How Car Exhaust System Works," 2013)

The reaction of nitrogen oxide with catalyst producing nitrogen gas, N_2 and oxygen gas, O_2, Figure 4 (Sankararaj, 2013).

$$2NO_2 \rightarrow N_2 + 2O_2.$$

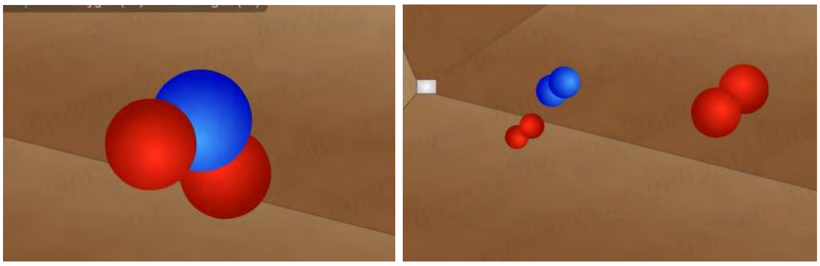

Figure 4 Reaction in first Ceramic Block ("How Car Exhaust System Works," 2013)

The reacted gases, N_2 and O_2 along with the other gases CO and HC were then exit first ceramic block and being sent to second ceramic block of oxidation catalyst containing platinum (Pt) and palladium (Pd) (Sankararaj, 2013).

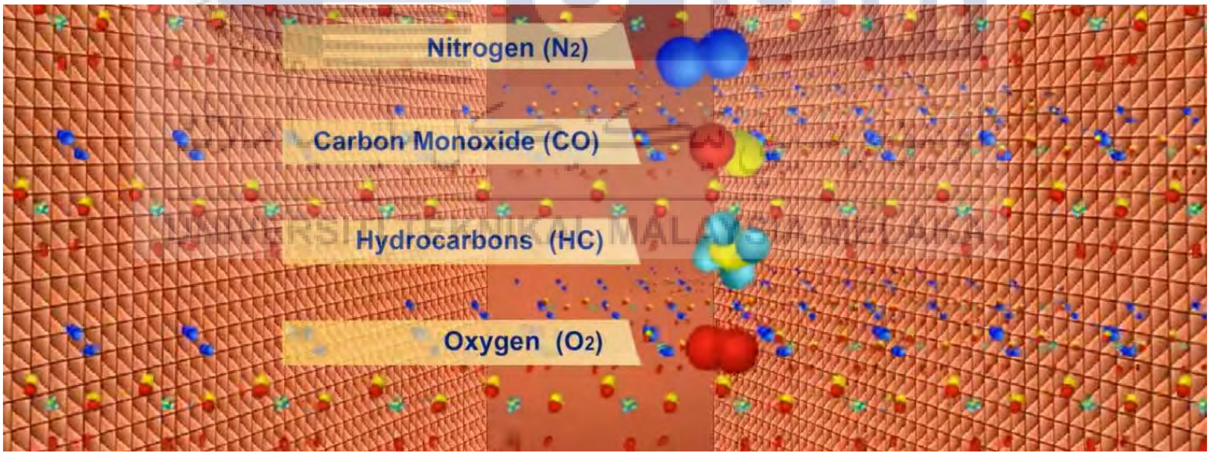

Figure 5 Gases Enter the Second Ceramic Block ("How Car Exhaust System Works," 2013)

The reaction of carbon monoxide, CO and oxygen gas,O_2, Figure 6 taken place inside the oxidation catalyst block producing carbon dioxide, CO_2 (Sankararaj, 2013).

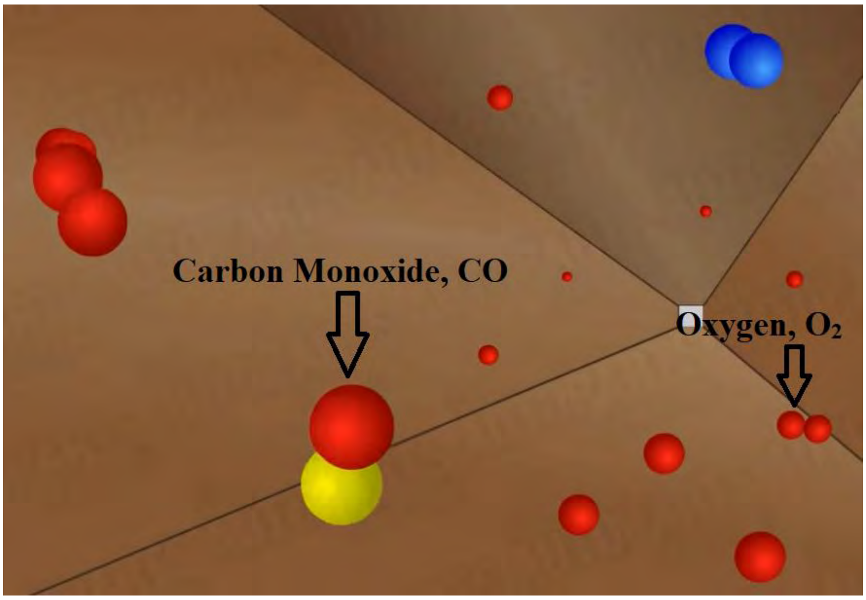

Figure 6 CO and O_2 Reaction (“How Car Exhaust System Works,” 2013)

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The reaction takes place producing CO_2 as shown in Figure 7.

$$2CO + O_2 \rightarrow 2CO_2$$

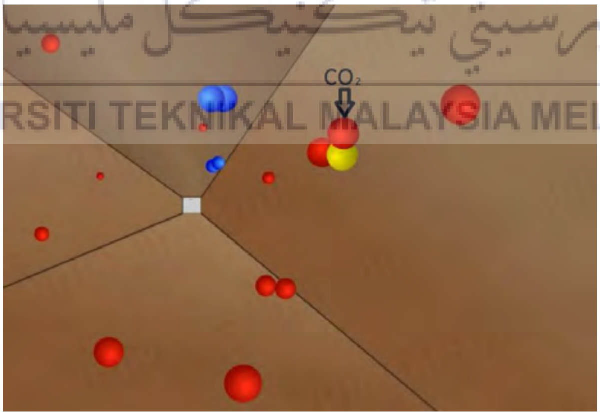

Figure 7 Carbon Dioxide Produced (“How Car Exhaust System Works,” 2013)

Hydrocarbon, HC that pass through second ceramic block also under go reaction with O_2 as shown in Figure 8 (Sankararaj, 2013).

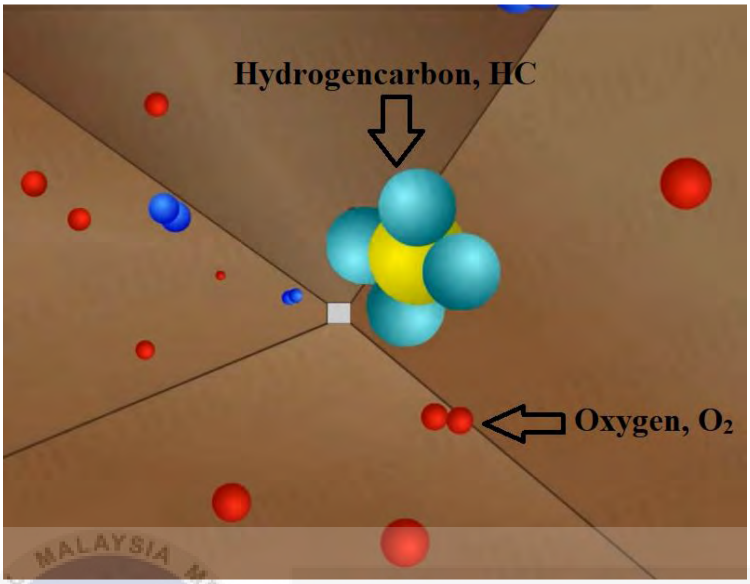

Figure 8 Hydrocarbon Reaction ("How Car Exhaust System Works," 2013)

This reaction thus producing water and carbon dioxide, Figure 9.

$$HC + O_2 \rightarrow H_2O + CO_2$$

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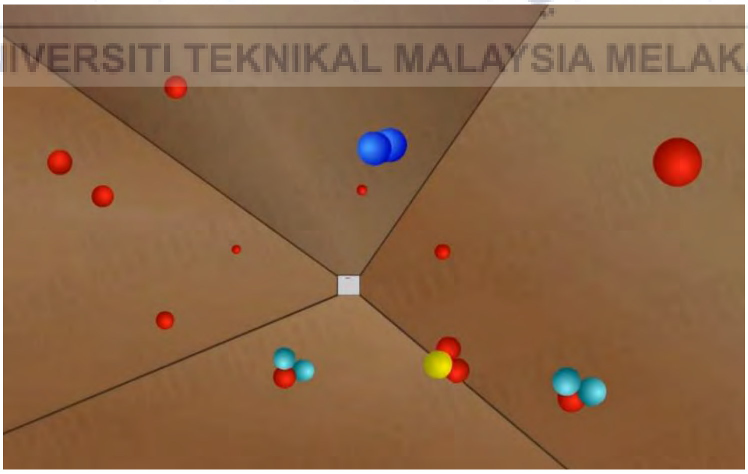

Figure 9 Formation of H_2O and CO_2 ("How Car Exhaust System Works," 2013)

At the end of the process occur inside the TWC, the less toxic gases was produced. Those gas are CO_2, N_2 and H_2O as illustrated in Figure 10 (Sankararaj, 2013).

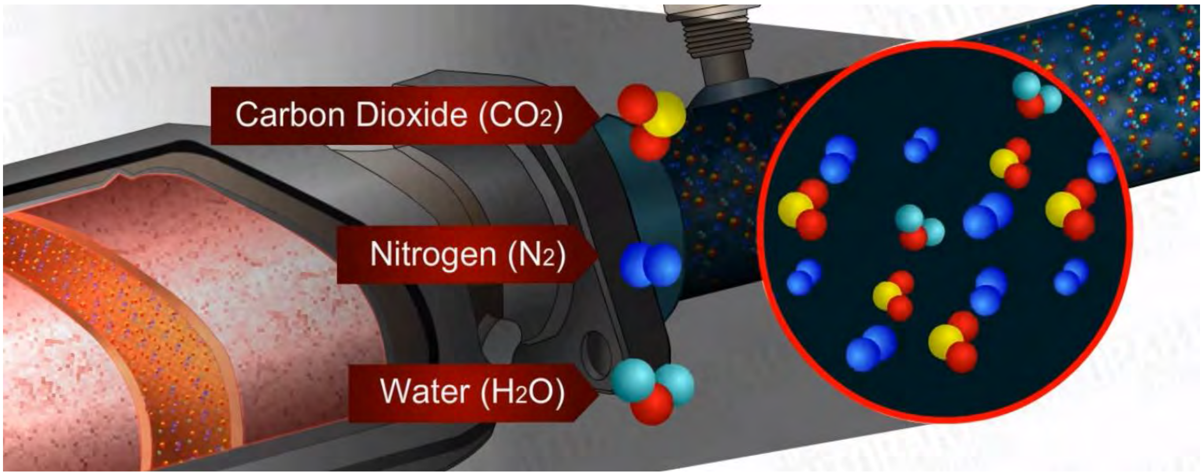

Figure 10 Less Toxic Gases Emitted ("How Car Exhaust System Works," 2013)

The rate of conversion can be achieved is nearly to perfection of 100% (Chang et al., 2014) (Chen & Chang, 2015). The usual conventional TWC light-off temperature can be reached when it is above 400°C (Chen & Chang, 2015).

The balance equation of the reaction taken place along the TWC are:

$$2NO + 2CO \rightarrow N_2 + 2CO_2$$

$$2CO + O_2 \rightarrow 2CO_2$$

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

In reducing temperature performance of three-ways catalyst (TWC), the development of new $Al_2O_3/CeO_2/ZrO_2$ mixed oxide of the same configuration was introduced to replace the old CeO_2/ZrO_2 mixed oxide and can reduce the light-off temperature by 50°C (Chang et al., 2014).

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2.2. ELECTRICAL HEAT CATALYST (EHC)

EHC is an appliance used to reduce exhaust emission (Pfalzgraf et al., 1995). It is useful in temperature management of exhaust aftertreatment effectively by reduction of HC, CO and NOx, have some impact in CO_2 reduction and fuel saves (Knorr, Ellmer, Maiwald, Schatz, & Brück, 2015). It acts as a catalyst to lower reduction of gases emission during cold start engine by becoming the heating catalyst and was electrically powered (Pfalzgraf et al., 1995). In cooperating with emission requirement standard, EHC can reduce time of catalyst heating to reach cut off temperature (Pace & Presti, 2011).

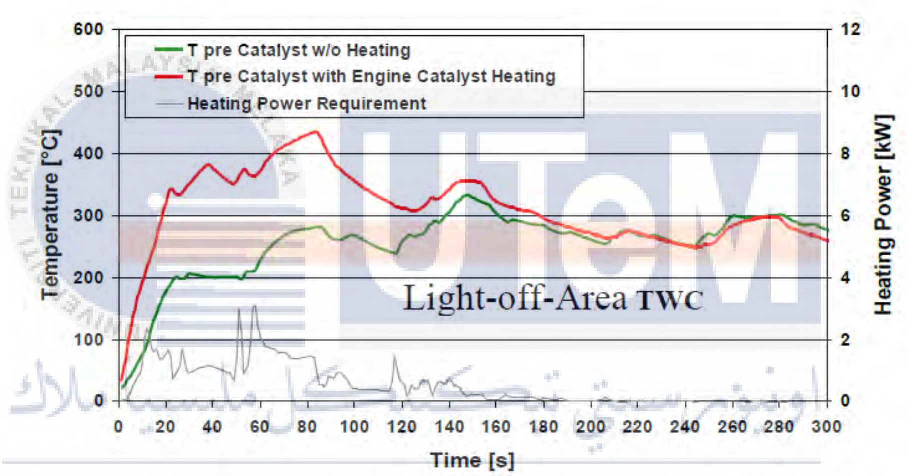

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Figure 11 Temperature Comparison with and without Catalyst Heater (Pace & Presti, 2011)

. The components needed to run the system are heating catalyst, electricity supply, electronic control, cables, plug and socket connection and secondary air system (Pfalzgraf et al., 1995). EHC can be placed whether as pre-catalyst by placing it close to the engine or before the main catalyst in the underbody area (Pfalzgraf et al., 1995). According to the studies of the effect of EHC on the emission of CO by Computational Fluid Dynamic (CFD), it was found to be more effective and perform higher reaction by placing EHC at the inlet of three ways catalytic converter (Mianzarasvand, Shirneshan, & Afrand, 2017).

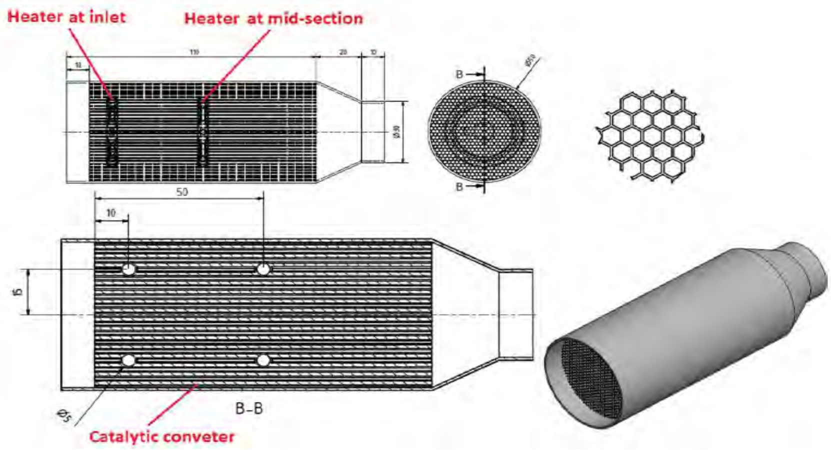

Figure 12 Illustration of Heater Position Along Catalytic Converter (Mianzarasvand et al., 2017)

The test performed shows that the minimum temperature for catalytic converter to light-off is 450K.

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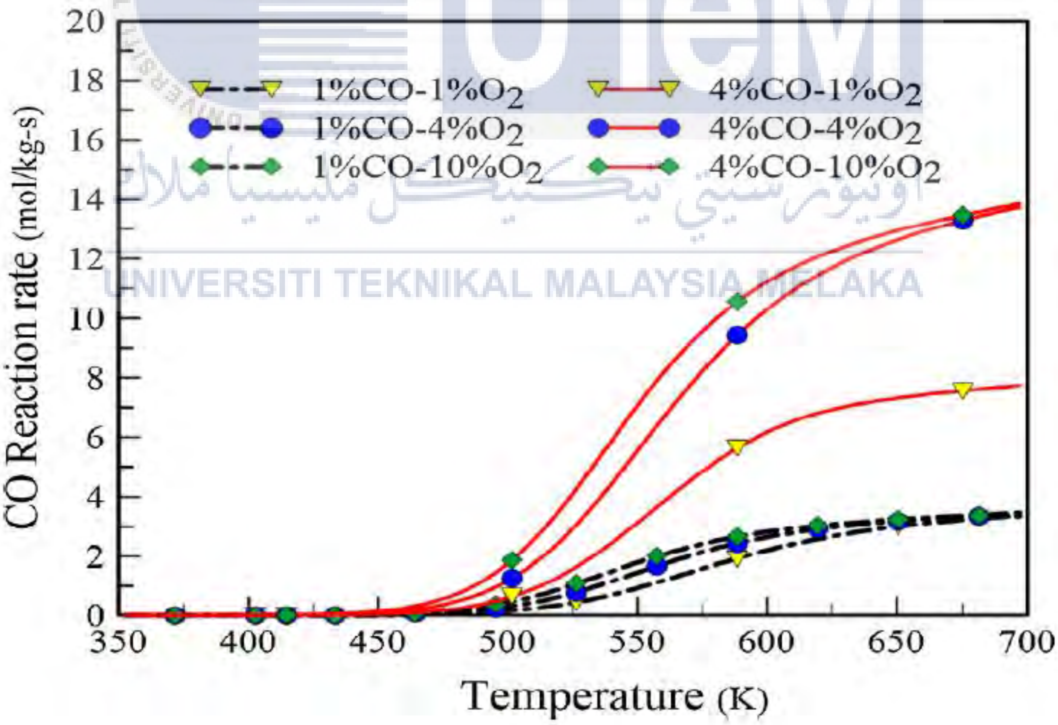

Figure 13 Activation Temperature of Catalytic Converter (Mianzarasvand et al., 2017)

There are several manufacturers of EHC production including Camet, Emitec, Kemira, Roth for the foil catalyst type and Corning and NGK for the extruded catalyst type.

However, extruded type offers slower heating up and higher mass compared to foil catalyst type (Pfalzgraf et al., 1995).

EHC needs only periodically short time heating time during start phase. Since different engine type require different vehicle exhaust configuration, the power supply also will be different (Figure 14). The provided electric heating capacity must be sufficient to activate the EHC at temperature of 280 ºC to 330 ºC in about 10 seconds (Pfalzgraf et al., 1995).

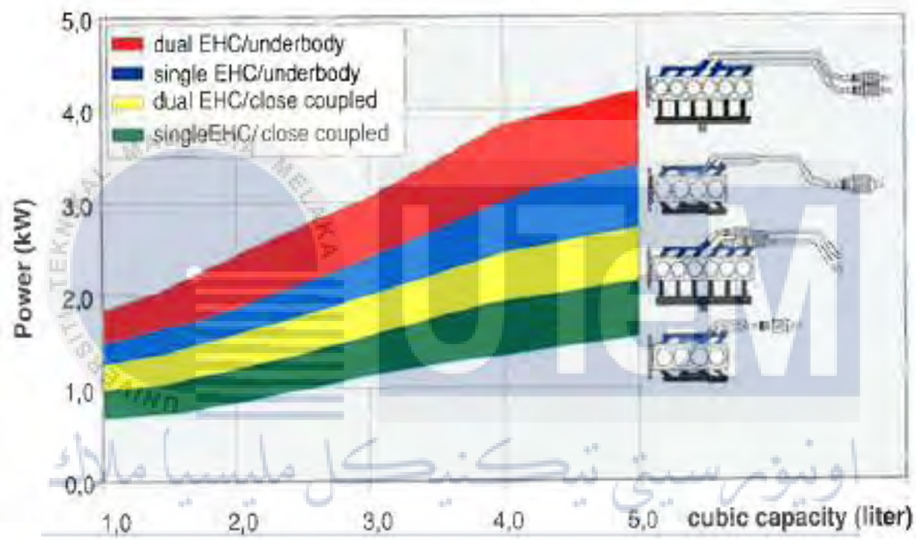

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Figure 14 Electrical Power Requirement in EHC of Different Vehicle Exhaust Configuration (Pfalzgraf et al., 1995)

2.3. EMISSION

Emission are gas produced during combustion process inside gasoline engine and emitted through exhaust system of a vehicle to the atmosphere. These gases consist of hydrocarbon, carbon monoxide and nitrogen oxide which was characterize as harmful gases to the environment and to human health. If it was not treated it can be the causes of many diseases and bring pollution.

2.3.1. Hydrocarbon, HC

Definition

The combination of hydrogens and carbons forming an organic compound called hydrocarbons. This formation between hydrogens and carbons can be achieved with single, double and triple bond. The bond between these two atoms are saturated hydrocarbon, when it was single bond (Figure 15) while double and triple bond (Figure 16) it will form an unsaturated hydrocarbon (Nicholas Gauthier, n.d.).

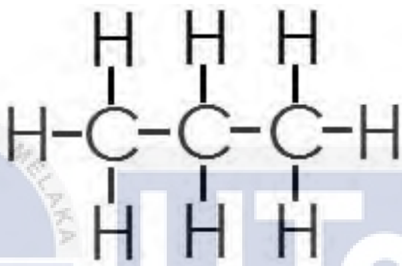

Figure 15 Saturated Hydrocarbon (Nicholas Gauthier, n.d.)

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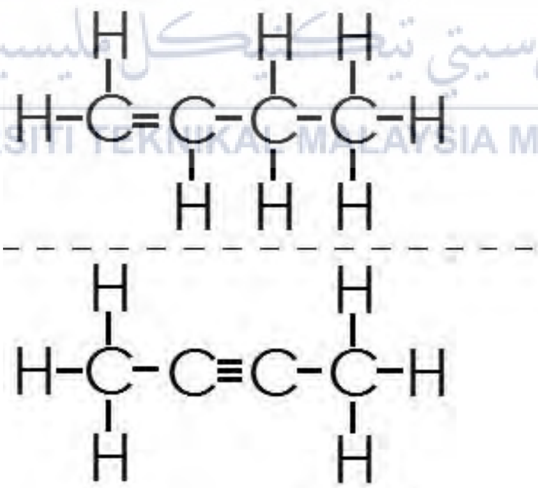

Figure 16 Unsaturated Hydrocarbon (Nicholas Gauthier, n.d.)

The causes of hydrogen gas formation are ("What Causes High Hydrocarbon (HC)?," n.d.):

i. Inappropriate Ignition Timing
ii. Ignition Part Faulty
iii. Lean Fuel Mixture
iv. Faulty Catalytic Converter

2.3.2. Carbon Monoxide, CO

Definition

Classified as poisonous gas which is colourless, tasteless and odourless (Occupational Safety and Health Administration, 2002). Carbon monoxide is a preventable cause of death which can occur by accidently breath in fire smoke. Aside from fire smoke, carbon monoxide was formed by vehicle exhaust emission and emission from industrial activity ("What is Carbon Monoxide (CO)," n.d.)

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The causes of carbon monoxide are:

i. Unclean Air Filter
ii. Oxygen Sensor Defect
iii. Faulty of Manifold Absolute Pressure Sensor
iv. Throttle Piston Sensor Faulty
v. Coolant Temperature Engine Sensor faulty

2.3.3. Nitrogen Oxides, NOx

Definition

Nitrogen oxide are gases consist of nitrogen and oxygen. This type of gas was produced by vehicle exhaust, burning of coal, oil, diesel fuel and natural gas and industrial activity (Town, n.d.).

The causes of nitrogen oxide emission are:

i. Lean fuel mixture
ii. Unresponsive Exhaust Gas Recirculation (EGR) system
iii. Faulty Catalytic Converter
iv. Engine was being used for too long
v. Overheating engine

2.4. SECONDARY AIR INJECTION SYSTEM

Nowadays catalytic converter can convert emitted toxic gases from engine up to more than 90% once it reaches the light-off temperature which is believed to be in the range of 300^{o}C to 350^{o}C. Before the catalytic converter reaches it light-off temperature, here where secondary air system in charge of recycling unburn HC back into exhaust manifold to reduce the emission of HC and CO during cold start phase (Pierburg, 2015).

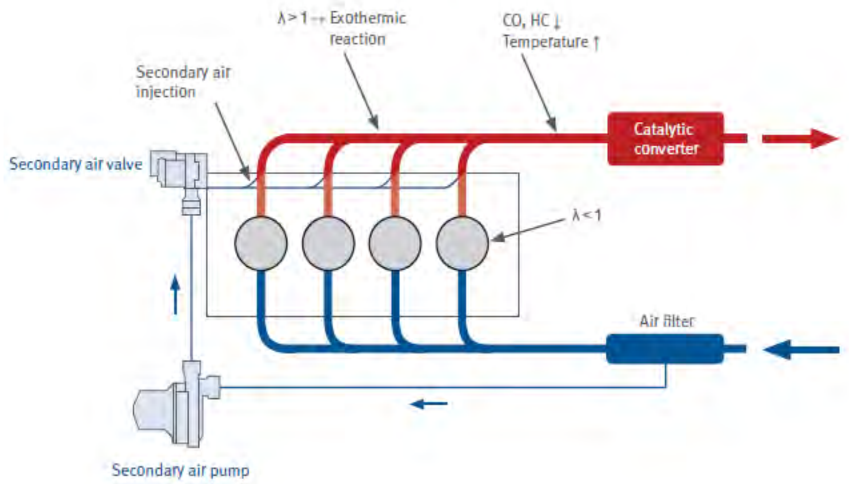

Figure 17 Secondary Air System (Pierburg, 2015)

In reducing the exhaust gas emission, it is believed one effective way is by controlling the combustion rate in combustion chamber. In that matter, some automotive company involved taking advance step in inventing new engine technology with the use of Gasoline Direct Injection to improve SI engine emission (Costa, Marchitto, Merola, & Sorge, 2014). The GDI operate differently under different combustion mode depends on the air fuel mixture. A stoichiometric or rich mixture is considered as high load while low load on the lean mixture.

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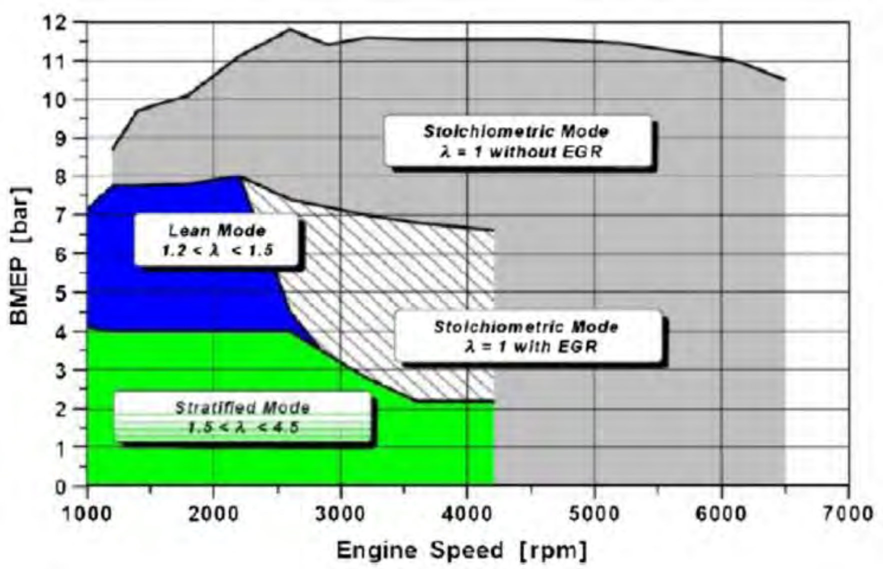

Figure 18 GDI Engine Operating Condition (Costa et al., 2014)

CHAPTER 3

METHODOLOGY

Methodology is the method that had been carried out to achieve the project objectives. Besides, this is the guideline for the accomplishment of the project. The project flows were divided into three parts which is project planning, milestone, experimental and data analysis.

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3.1. PROJECT PLAN

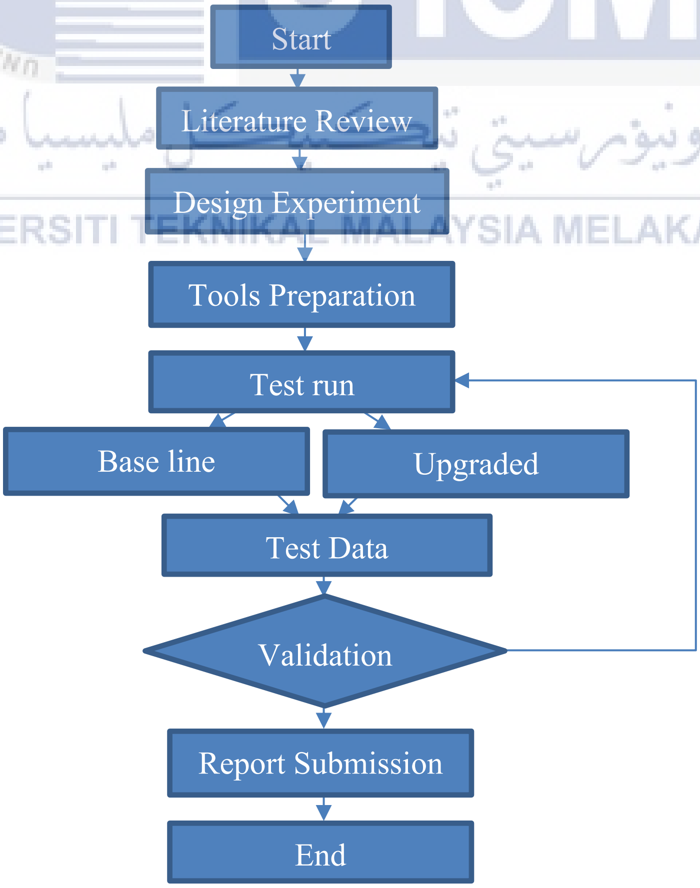

Figure 19 Project Plan

3.2 GANT CHART OF PROJECT PLANNER

Table 1 Gant Chart Planner

Activities / Week		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41
Research Title Selection																																										
Literature review																																										
Design of experiment																																										
Tools preparation																																										
Test run	Baseline																																									
	Upgraded																																									
Test data																																										
Validation																																										
Report writing																																										
Report submission																																										
PSM Seminar																																										

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3.3 EXPERIMENTAL METHOD

Experimental method is a method used to carry project experiment and test. This include fabrication process, material and appliance testing, the way the test was running and the procedure of the test. In this project, the experiment was divided into three phase which are appliances testing, fabrication and experimental test. Under the instrument testing, there were three tests done along the project which are electrical heater catalyst (EHC) heating element point test, gas emission analyser test and gas temperature recorder test just after leaving the engine into exhaust manifold.

3.3.1 Instrument Testing

This phase is about the test undergo to make sure that the device used are in good condition and can operate properly when being used during experiment and data collection.

3.3.1.1 E-heater heating element point test

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Heating element point test, Figure 20 was run to determine the flow of heating distribution of the EHC and to find out the defect heating element of the heater. Thermographic camera was used to capture the visual of the flow of heating process. The Emitec electrically heated catalyst was chosen as the EHC to be used in this project.

Objective

To look for any defect among the heater element inside electrical heated catalyst and to look for the heating distribution pattern.

Apparatus

1. Laptop equipped with FLIR ResearchIR Software
2. Power supply
3. Retort stand
4. Emitec electrical heated catalyst
5. Flir A655sc infrared camera

Table 2 Flir A655sc Infrared Camera Specification

Detector	
Detector type	Uncooled Microbolometer
Spectral Range	7.5 - 14.0 µm
Resolution	640 x 480
Detector Pitch	17 µm
NETD	<30 mK
Imaging	
Frame rate (Full Window)	50 Hz
Subwindow Mode	User-Selected 640 x 240 or 640 x 120 (Gigabit Ethernet only)
Max Frame Rate (@ Min Window)	200 Hz (640 x 120)

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Dynamic Range	16-bit
Digital Data Streaming	Gigabit Ethernet (50/100/200 Hz); USB (25 Hz)
Command and Control	Gigabit Ethernet
Measurement	
Standard Temperature Range	–40°C to 150°C (–40°F to 302°F) 100°C to 650°C (212°F to 1,202°F)
Optional Temperature Range	Up to 2,000°C (3,632°F)
Accuracy	±2°C or ±2% of Reading

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Procedure

1. Preparing apparatus needed for the heating element testing of EHC
2. Installing FLIR ResearchIR Software into the laptop
3. Connect EHC with the power supply to power up the heater
4. Connect cable from laptop to the FLIR thermographic camera
5. Run the software installed in laptop and turn on the power supply
6. Observe each of ten heating elements on the EHC recorded by thermographic camera through laptop to find out whether all the elements were well functioning or not.
7. Switch off the power supply and stop recording the thermographic camera.
8. Let the EHC cool down to the room temperature.
9. Repeat step 5 to 8 three times.
10. Compare the testing result gained.

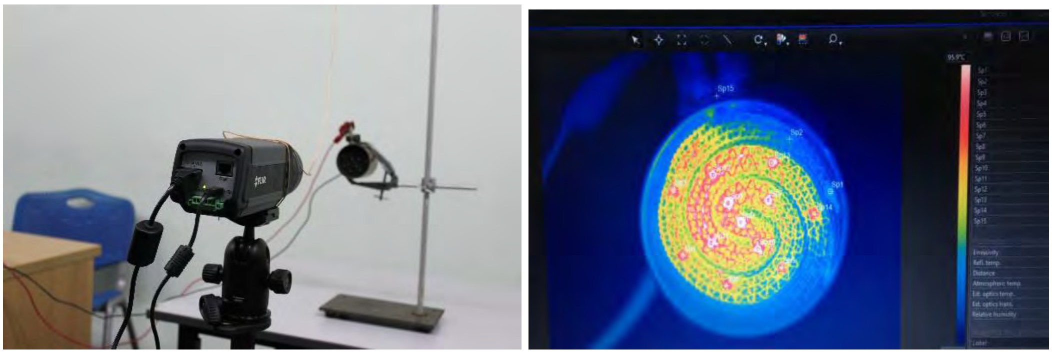

Figure 20 Heating Element Point Test

3.3.1.2 Gas Emission Analyser Test

Emission test was run to make sure that exhaust pipeline flow smoothly without clogged and catalyst were well function besides testing the condition of gas analyser. It’s done by observing gas release during engine in idle state with probe being placed inside the exhaust pipe that connected with EMS gas analyser Model 5002 to read the amount of hydrocarbon, carbon dioxide, carbon monoxide, oxygen gas and nitrous oxide release, Figure 21.

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Objective

To identify condition of exhaust pipe flow and catalyst reactivity before taking into experimental phase.

Apparatus

1. Stainless steel probe with 25 feet hose
2. Power supply
3. Proton Persona 1.6Ll

4. EMS gas analyser model 5002

Table 3 EMS Gas Analyser Model 5002 Specification

Power	10 -16 VDC (110/220 VAC 50/60 Hz optional)
Ranges	HC: 0 - 2000 ppm Low Range HC: 0-20,000 ppm High Range CO: 0 - 10% CO2: 0 - 20% O2: 0 - 25% NO: 0 - 5000 ppm (Nitric Oxide) *
Warmup	Less than 5 minutes
Display Resolution	HC: 1 ppm vol. CO: 0.01% vol. CO2: 0.1% vol. O2: 0.01% vol. NO: 1ppm*
Digital Display	3" x 5" LCD Displays all 5 gases, & AFR or LAMDA
Accuracy (BAR 97 EPA ASM)	HC: 4 ppm HC CO: 0.06% CO CO2: 0.3% CO2 O2: 0.1% O2 NO: 25 ppm*
Drift	Zero and span drift are less than ± 0.6% of full scale for the first hour and less than ± 0.4% of full scale per hour thereafter.

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System Response Time	Bench: 1.5 Sec/25 ft. hose 5 sec. to 90% of final reading
Ambient Conditions	35F (2C) to 120F (45C), rel. humidity 0-98%
Sample Hose	25 feet (7.5 m) with QD coupling /200 F Degrees Max.
Sample Probe	Stainless steel 1200 Degrees F (replaceable flex tip)
Mass	Approx.: 10 LBS. (4.5 kg)

Procedure

1. Prepare Proton Persona as the testing car and make sure it is in a good condition.
2. Turn ON the EMS gas analyser model 5002 and wait for preheating and zeroing process before use.
3. Place the probe into the exhaust pipe as shown in Figure 22.
4. Switch on the engine then observe and analyse the EMS digital display to make sure that the gas analyser can be run smoothly.
5. Switch OFF the engine when the EMS gas analyser was confirmed in a well condition.

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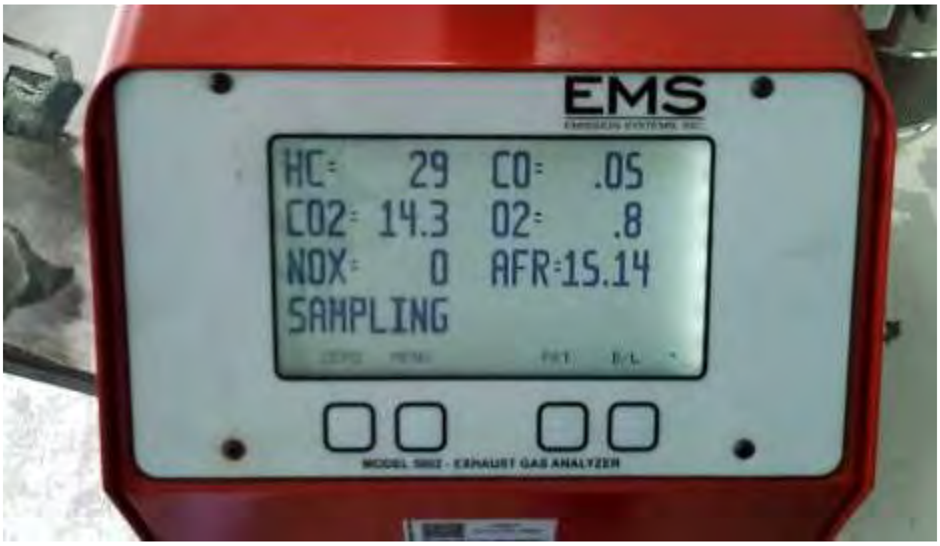

Figure 21 EMS Gas Analyser

Figure 22 Probe Placed Inside Exhaust Pipe

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3.3.1.3 Gas Temperature Test

This test was conducted to take the reading of gas temperature at the exhaust pipeline using thermocouple that were installed at certain point along exhaust pipeline after the exit of combustion chamber as shown in Figure 24 under idling state.

Objective

To make sure thermocouple were properly installed and in great condition for experiment and data collection.

Apparatus

1. Exhaust pipeline.
2. Type K thermocouple
3. Miniature thermocouple input connector
4. PicoLog Recorder Software
5. USB TC-08 Thermocouple Data Logger, Figure 23

Table 4 USB TC-08 Thermocouple Data Logger Specification

Item	**Specification**
Number of channels (single unit)	8
Maximum number of channels (using up to 20 TC-08s)	160
Conversion time	100 ms per thermocouple channel + 100 ms for cold junction compensation (CJC can be disabled if all channels used as voltage inputs)
Temperature accuracy	Sum of ±0.2% of reading and ±0.5 °C
Voltage accuracy	Sum of ±0.2% of reading and ±10 µV
Overvoltage protection	±30 V
Maximum common-mode voltage	±7.5 V

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Input impedance	2 MΩ
Input range (voltage)	±70 mV
Resolution	20 bits
Noise-free resolution	16.25 bits
Thermocouple types supported	B, E, J, K, N, R, S, T
Input connectors	Miniature thermocouple
Dimension	201 x 104 x 34 mm (7.91 x 4.09 x 1.34 in)
Operating temperature	0 to 50 °C
Operating temperature stated accuracy	20 to 30 °C
Operating humidity	5 to 80 %RH non-condensing
Storage humidity	5 to 95 %RH non-condensing
Water resistance	Not water-resistant

Thermocouple type	Overall range °C	0.1 °C resolution	0.025 °C resolution
B	20 to 1820	150 to 1820	600 to 1820
E	–270 to 910	–270 to 910	–260 to 910
J	–210 to 1200	–210 to 1200	–210 to 1200
K	–270 to 1370	–270 to 1370	–250 to 1370
N	–270 to 1300	–260 to 1300	–230 to 1300
R	–50 to 1760	–50 to 1760	20 to 1760
S	–50 to 1760	–50 to 1760	20 to 1760
T	–270 to 400	–270 to 400	–250 to 400

Figure 23 Pico Data Logger

Procedure

1. Prepare all apparatus needed to run the test.
2. Install PicoLog Recorder software into laptop to be use when recording data.
3. Install thermocouple into the hole that was made along the exhaust pipeline as in Figure 24.
4. Connect thermocouple with data logger that was connected to the laptop using miniature thermocouple input connector as shown in Figure 25.
5. Run PicoLog Recorder software.
6. Start the engine and simultaneously start recording the temperature.
7. Observer the behaviour of data recorded and validate.
8. Switch off the engine and stop recording when the data recorded shown apparatus setup was in good shape to be use when running experiment.

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Figure 24 Thermocouple Placement at the Manifold

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Figure 25 Connection of Laptop, Data Logger and Thermocouple

3.3.2 Fabrication

This section described on the fabrication process throughout the project. The fabrication done is about installation of EHC before three ways catalyst to decrease time taken to heat up the catalyst thus help enhancing the reaction process for a better performance and less harm gas emission.

Step 1: Basement as holder for EHC.

Electrical Heating Catalyst were firstly equipped with basement at both end as the holder when being installed between exhaust manifold and three ways catalyst. Two plates were welded to the EHC as the basement using arc weld.

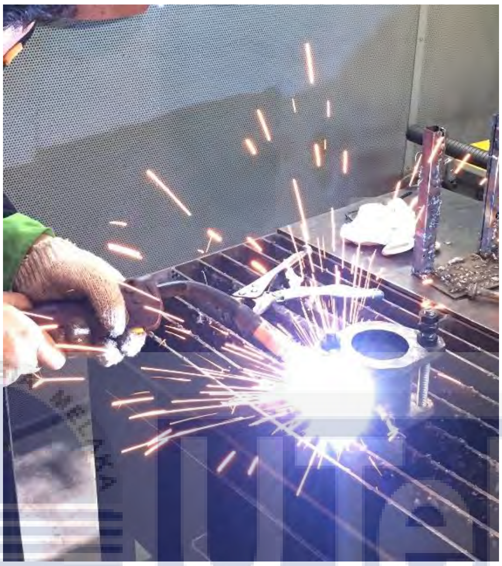

Figure 26 Welding Process Sticking Plate to EHC

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Step 2: Thermocouple and air injection installation

Five holes were made (two on the exhaust manifold and three on UTWC) to install one set of air injection nozzle and four sets of thermocouples. The air injector was installed at the inlet of three ways catalyst and two pairs of thermocouples were each installed on both exhaust manifold and UTWC.

Step 3: Installation of EHC

Figure 27 shows the arrangement between exhaust manifold and UTWC before installation of EHC.

Figure 27 The Arrangement of Exhaust Manifold and UTWC

On Figure 28, it shows how the arrangement of the exhaust system after installation of EHC.

Figure 28 Arrangement of Manifold, EHC and UTWC

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3.3.3 Experimental Test

Experimental test was done to observe and collect data from the baseline setup and after a few modifications done based on the theoretical statement founded by citation of some trusted sources. Running the experimental test will give the result of before and after modification on a system that operates with actual condition and situation.

Objective

To collect data and do some observation on the effect of modification of a system as compared to the previous conventional system.

Apparatus

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1. Emitec Electrical Heated Catalyst (EHC)
2. Close Couple Catalyst (CCC)
3. Underfloor Three Ways Catalyst (UTWC)
4. Stainless steel probe with 25 feet hose
5. Power supply system
6. Proton Persona 1.6L
7. EMS gas analyser model 5002
8. Exhaust pipeline.
9. Type K thermocouple
10. Miniature thermocouple input connector
11. PicoLog Recorder Software
12. USB TC-08 Thermocouple Data Logger

Procedure

1. Prepare apparatus needed to run the experimental test including proton persona 1.6L.
2. Install the close couple catalyst (CCC) to the exhaust pipeline.
3. Install the thermocouple type K on the exhaust pipeline to take the reading of temperature inside the pipeline.
4. Connect thermocouple with USB TC-08 thermocouple data logger using miniature thermocouple input connector and connect it to the laptop installed with PicoLog Recorder software.
5. Run PicoLog Recorder software installed on laptop to record the temperature reading along the experimental test using Pico data logger.
6. Insert gas analyser stainless steel probe into the exhaust exit and connect it with the EMS gas analyser model 5002 to record the amount of gas exit from the exhaust and the data will be collected manually.
7. Start the engine with simultaneously start recording using EMS gas analyser and the PicoLog Recorder to record gas emission and temperature change inside the exhaust pipeline.
8. Switch the engine and save the data gained by running the experiment.
9. Replace the CCC along the pipeline with underfloor catalyst, EHC and air injection system.
10. Repeat step 3 until 8 using UTWC alone without turning on EHC and air injection.
11. Collect and save data gained from the test.
12. Repeat step 3 until 8 using UTWC with EHC and air injection being turned on.
13. Collect and save data gained from the test.

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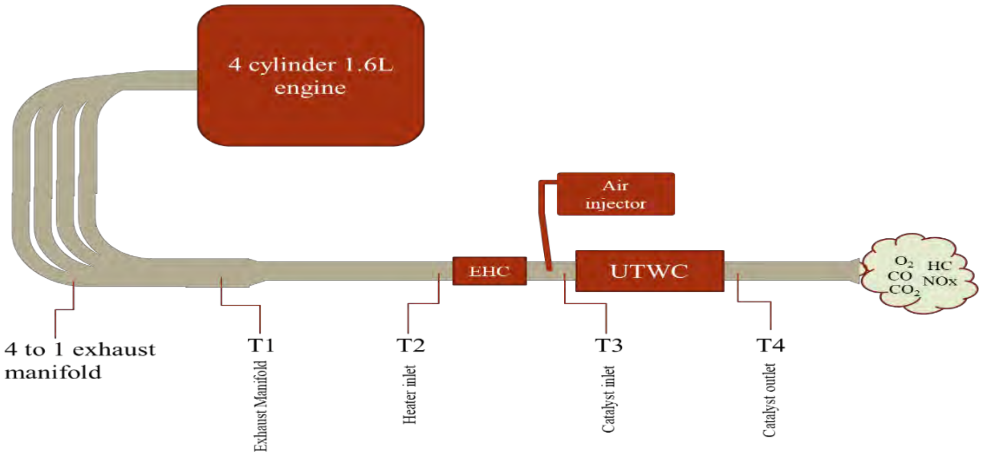

Figure 29 Schematic Diagram of Fabricated Testing System

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CHAPTER 4

RESULT AND DISCUSSION

This chapter focus on the result gained from test conducted and discussion regarding the data collected.

4.1. GAS EMISSION DATA AND RESULT

Exhaust gas emission and temperature result was obtained by running emission test using EMS gas analyser**, Figure 21** and **Figure 22** and Pico data logger **Figure 23.** The test result is data collected when running the test for under several conditions which is in idling state for baseline using close couple catalyst (CCC), baseline using underfloor three ways catalyst and when UTWC equipped with EHC and air injection system and some parameters were considered. The parameters considered in the experiment are emission gas temperature (EGT), time, hydrocarbon (HC), carbon monoxide (CO), nitrogen oxide (NOx), carbon dioxide (CO_2) and oxygen gas (O_2) content.

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4.1.1. Close Couple Catalyst (CCC)

The baseline emission test was conducted to analyse the exhaust performance before being modified. The baseline result was conducted using originally equipped close couple catalyst (CCC) comes with 1.6L Proton Perdana. This section will describe the result of baseline test and the results were shown in Figure 30 for emission gas content and Figure 31 for its temperature before entering CCC along exhaust pipe against time during idling state from cold start.

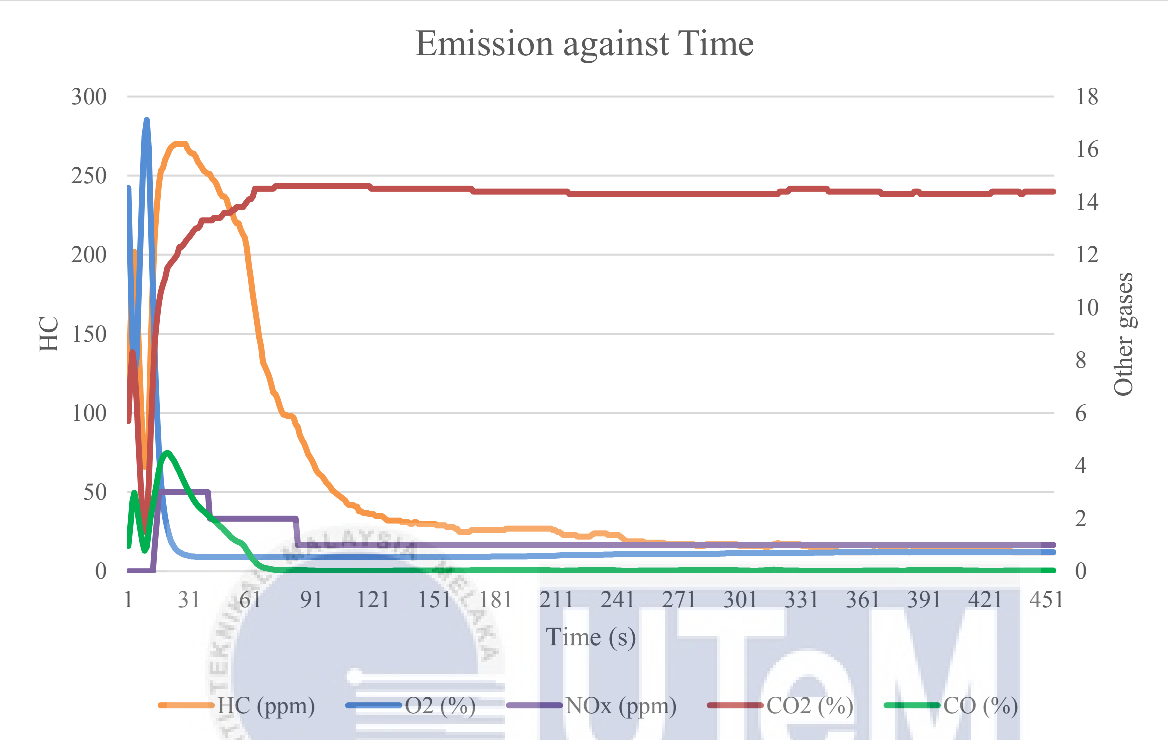

Figure 30 Emission Against Time Using CCC

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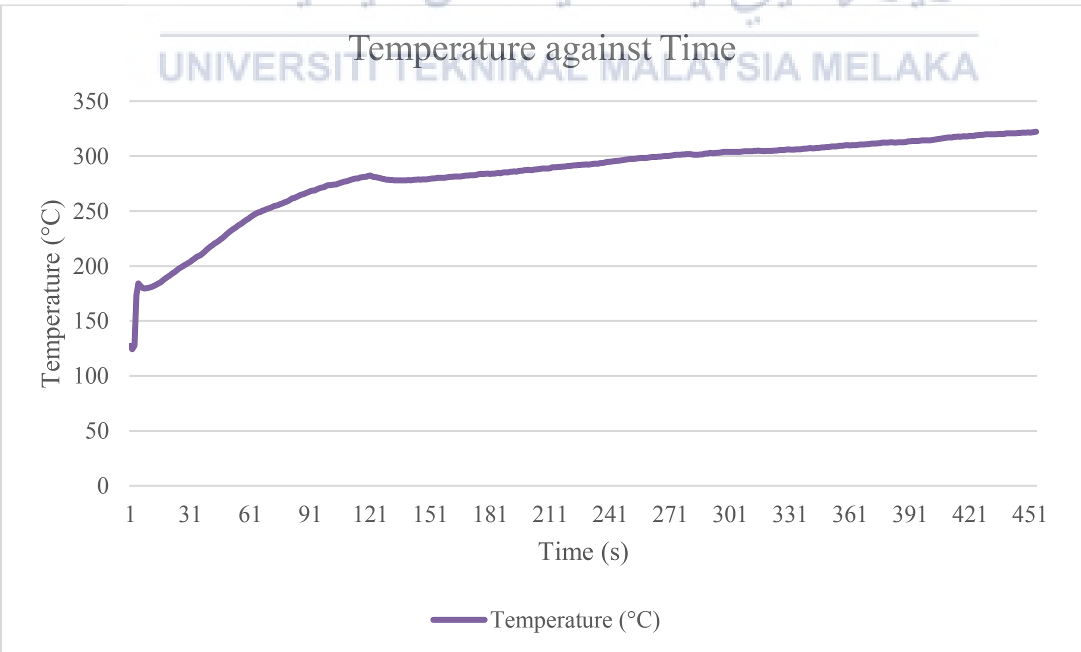

Figure 31 Temperature Against Time Using CCC

The result collected from the test when the exhaust system was equipped with close couple catalyst (CCC) shown that the catalyst had shown the sign of activation at the 28th second when the exhaust temperature was around 202 °C and the hydrocarbon started to decrease form 270 ppm to 25 ppm at its stable state around 162 second after the engine was start from cold. The catalyst was at its light-off temperature during the 54th second when temperature reaching 236 °C as there was sudden reduction of HC on that moment. The decrease of hydrocarbon content continues until 12 ppm at idling state on 433th second. The other gases also show significant changes staring from 28th second when oxygen gas (O_2) raise from 0.62% to 0.72%, nitrogen oxide (NOx) decrease from 3 ppm to 1 ppm, carbon dioxide (CO_2) increase from 12.5% to 14.4% and carbon monoxide (CO) reduce from 3.27% to 0.03%.

4.1.2. Underfloor Three Ways Catalyst

This section shows and analyse the result when the close couple catalyst (CCC) was replaced with underfloor three ways catalyst (UTWC) on its emission (Figure 31) and temperature (Figure 32) against time.

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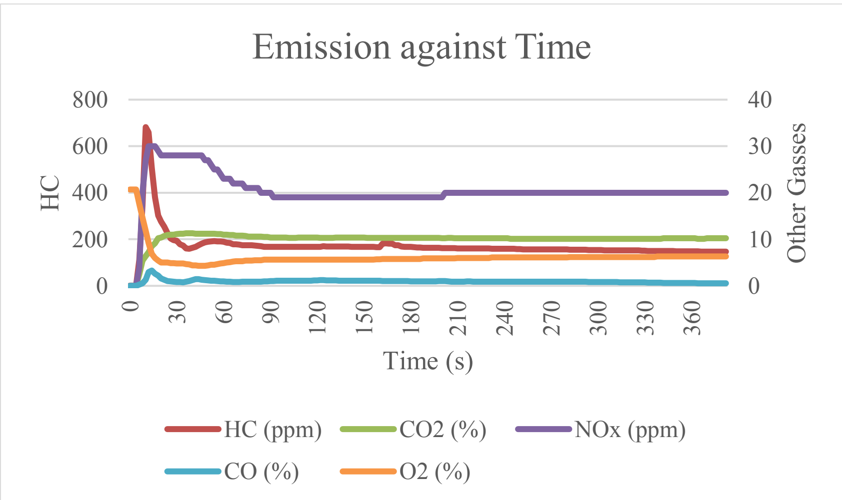

Figure 32 Emission Against Time Using UTWC

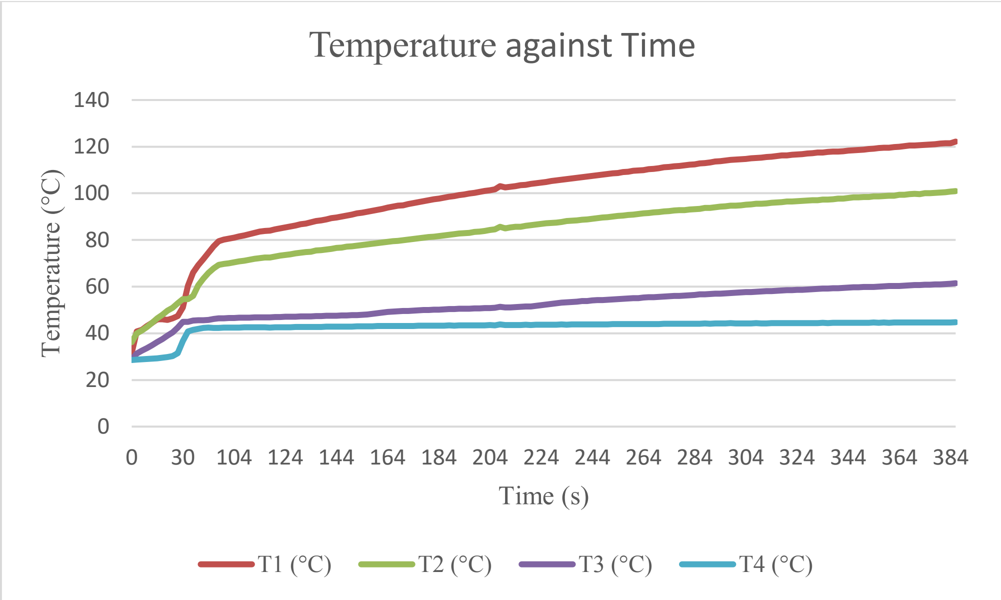

Figure 33 Temperature Against Time Using UTWC

In this test, underfloor three ways catalyst (UTWC) was used as a replacement of close couple catalyst (CCC) which means that the catalyst was dragged further away from exhaust exit manifold. the test was run without assistance from the electrical heated catalyst (EHC) and air injection system. Four points of gas temperature were being taken which were at the exhaust manifold (T1), EHC inlet (T2), UTWC inlet (T3) and UTWC outlet (T4).

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From the result, it shows that by dragging the catalyst further away causing the catalyst to not being fully activated. This can be proved by the higher amount of hydrocarbon (HC), carbon monoxide (CO) and nitrogen oxide (NOx) and lower amount of carbon dioxide (CO_2), Figure 32 as compared when using close couple catalyst. This happened due to the lack existence of heat that help in reaching catalyst light-off temperature. As was shown on Figure 33, the highest temperature is at the exhaust manifold while at the outlet of catalyst shows a lot lower temperature. This happened since exhaust manifold was placed nearest to the combustion chamber exit. As the position going further, there were a lot of heat loss along the travel through the exhaust pipeline. That makes the exhaust manifold receiving highest heat followed by EHC inlet, catalyst inlet and catalyst outlet as the lowest heat receiver.

4.1.3. Underfloor Three Ways Catalyst with EHC and Air Injection

This section will describe and analyse the result of emission and temperature inside the exhaust pipeline when equipped with electrical heat catalyst (EHC) and air injection system alongside underfloor catalyst at four different points.

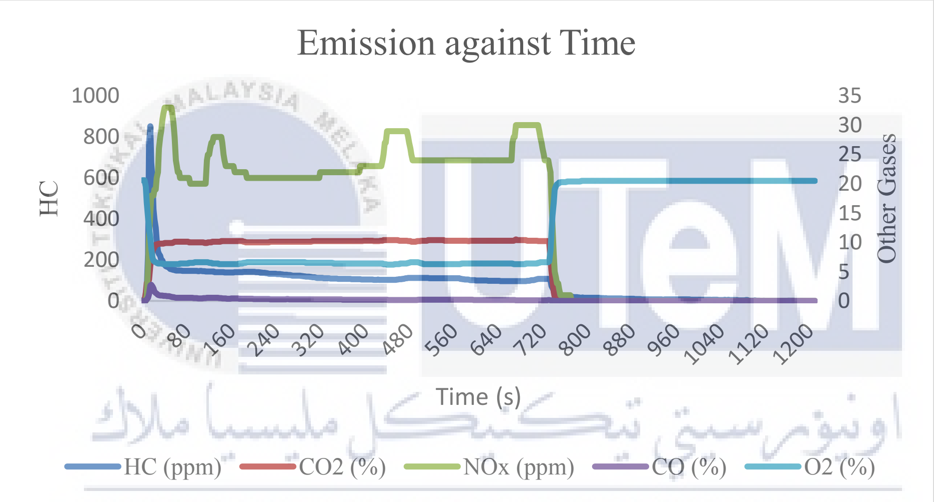

Figure 34 Emission Against Time with UTWC, EHC and Air Injection

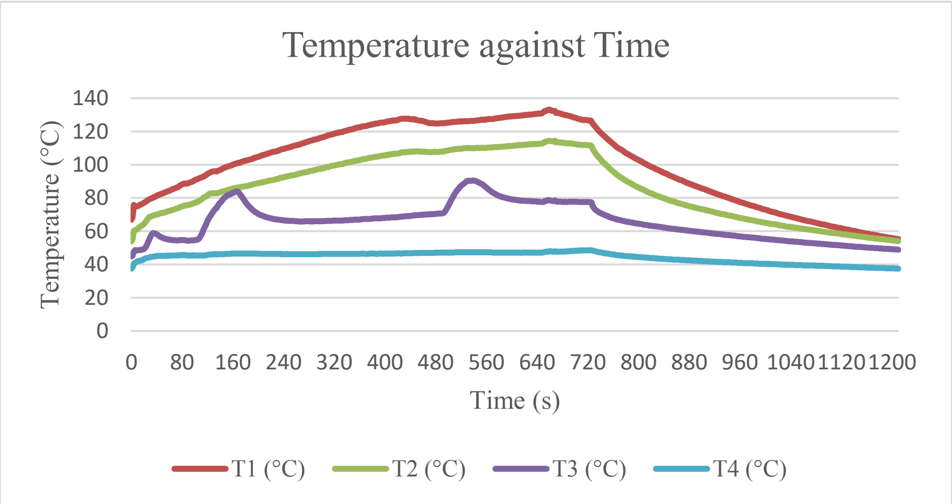

Figure 35 Temperature Against Time with UTWC, EHC and Air Injection

From the result obtained, during 13th second until 23rd second when the heater was turned on, it helps in increasing of temperature at heater outlet and catalyst inlet. Hydrocarbon also shows changes with a little decrease in its amount during this 10 second period. The other result shown changes in decrease of CO and increase of CO_2 and NOx. With the increase of NOx, it can be said that there was not enough reaction occur in low temperature inside catalyst that can help reducing NOx content.

The heater was then turned on again from 98th second until 158th second. During this longer period the heater was turned on, it shows some increase in catalyst inlet temperature from 76°C up to 85°C. This increase of temperature somewhat gives positive results with the decrease of HC and CO and increase of CO_2. As for NOx, it shows increase value from the start of heating before going down from 28ppm on 142nd second when the temperature was about 78°C till 23ppm on 158th second with 82.5°C catalyst inlet temperature. It shows that catalyst only started to react in reducing amount of NOx when the inlet catalyst temperature reaching 78°C.

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On the same moment, during the EHC was turned on, there were presence of air being injected between EHC outlet and UTWC inlet starting from 131st second. This injection somewhat reduces the gradient increase of inlet catalyst temperature as the presence of air flow slowdown the rate of heating the catalyst. However, the content of HC, NOx and CO continue to reduce and the amount of CO_2 showing increasing value. The presence of air flow only slowdown the rate of heating up catalyst but not stopping the temperature from increase.

When the electrical heated catalyst was turn off on the 158th second with the air continue to flow into the exhaust pipeline, there were quiet high rate of reduction in temperature at catalyst inlet starting from 166th second. The graph shows reduction in temperature reading from 83.97°C down to 65.83°C on the 270th second. During this period, the hydrocarbon graph gives a fluctuate pattern when the reading shows increase of HC content from 166th second 140ppm to 142ppm on the 182nd second before going down staring from 206th second until the reading was 124ppm on the 270th second. When the catalyst was supply with only air injection from 158th second until 474th second, there was drastic decrease in catalyst inlet temperature. On the amount of gas, HC, CO_2 and CO has shown a little change while NOx seems to show increase in number since the temperature is not enough to start the reaction in conversion of NOx that was claimed to be around 70°C.

The heating and air injection phase were then repeated when EHC was turned back on from 485th second until 548th second and air was injected from 521st second until 548th second and there seems to be not too much changes in HC, CO, NOx and CO_2 content analysed by gas analyser. The engine was then being turned off during 720th second.

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CHAPTER 5

CONCLUSSION AND RECOMMENDATION

5.1. CONCLUSSION

In reducing the time taken to heat up catalyst of three ways catalyst (TWC) along the exhaust pipeline, the use of electrical heated catalyst (EHC) seems the best alternative to be taken to overcome the problem. The function of EHC that provide instant heat to the catalyst during cold start helps to drastically increase the temperature at the catalyst inlet so that the catalyst can reach its light-off temperature in a short period of time while waiting the supply of heat from the exhaust gas emission as the product of engine combustion. With a little help from the air injected by the air injection system seems can enhance the process of combustion to burn the incomplete burn of hydrocarbon (HC) comes from engine combustion. A replacement of close couple catalyst (CCC) with underfloor three ways catalyst (UTWC) means that the catalyst was being dragged further away from the exhaust manifold and the catalyst could not exploit the high temperature gas release during exhaust stroke. The further the catalyst from the exhaust manifold, the lower the gas temperature received by the catalyst. With that matter the use of EHC seems reliable to help raise gas temperature and presence of air from air injection assistance can increase the rate of HC burn at the EHC before entering the catalyst with high temperature. However, due to this new system it seems that there were a lot of heat loss along the process. Although EHC can assist in increase the gas temperature and burning of incomplete burn HC, the use of EHC for a long period of time can cause the drainage of vehicle battery power as the EHC was powered by the vehicle

12V battery. As for the use of air assisted injection system, the supply of air flow can reduce the temperature of heat produce by the EHC that supposed to raise the temperature for catalyst activation. This presence of air flow is the same as blowing a hot tea so that the temperature will reduce and more suitable to be drink. Thus, the use of secondary air injection is not suitable especially with an exhaust treatment system that already causing too much heat loss due to the placement of catalyst further away from the exhaust manifold.

5.2. RECOMMENDATION

From the study, there were several actions can be taken to improve the performance of exhaust gas treatment to produce a better system to treat the harmful gasses for human health and environment. One of them is by not placing the catalyst too further away from the exhaust manifold. This is to make sure the catalyst can use full benefit of high temperature exhaust gas and exploit them to reach light-off temperature where catalyst started to work in converting harmful gasses, HC, CO and NOx into a greener earth gas like CO_2, N_2 and O_2 with higher efficiency.

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The other improvement to be taken in future study is on the power supply of electrical heated catalyst (EHC). As being mention in conclusion, the continuous use of EHC for a long period of time can cause the 12V vehicle battery to get drained. Thus, it's the best to produce a secondary battery that were enough to supply power to the EHC and is equipped with rechargeable system. The recharged power system must be generated due to the recycle from operation when the vehicle is being use. As the example is using dynamo to generate power with the rolling of the tyre or the use of thermoelectric generator to take advantage of high temperature at the exhaust pipeline to be converted into electrical power so that it can recharge the battery without disturbing the main battery.

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APPENDICES

APPENDIX A

Flir A655sc Infrared Camera Specification

Imaging Specifications

System Overview	FLIR A655sc
Detector Type	Uncooled Microbolometer
Spectral Range	7.5 – 14.0 μm
Resolution	640 × 480
Detector Pitch	17 μm
NETD	<30 mK
Imaging	
Time Constant	<8 ms
Frame Rate (Full Window)	50 Hz
Subwindow Mode	User-Selectable 640 × 240 or 640 × 120
Maximum Frame Rate (@ Min. Window)	200 Hz (640 × 120)
Dynamic Range	14-bit
Digital Data Streaming	Gigabit Ethernet (50/100/200 Hz) USB (25/50/100 Hz)
Command and Control	Gigabit Ethernet, USB
Measurement	
Standard Temperature Range	–40°C to 150°C (–40°F to 302°F) 100°C to 650°C (212°F to 1,202°F)
Optional Temperature Range	Up to 2,000°C (3,632°F)
Accuracy	±2°C or ±2% of Reading
Optics	
Camera f/#	f/1.0
Available Lenses	6.5 mm (80°), 13.1 mm (45°), 24.6 mm (25°), 41.3 mm (15°), 88.9 mm (7°)
Focus	Automatic or Manual (Motorized)
Close-up / Microscopes	Close-up 25 μm, 50 μm, 100 μm
Image Presentation	
Digital Data	Via PC Using ResearchIR Software
General	
Operating Temperature Range	-15°C to +50°C (+5°F to 122°F)
Storage Temperature Range	-40°C to 70°C (-40°F to 158°F)
Encapsulation	IP 30 (IEC 60529)
Bump / Vibration	25 g (IEC 60068-2-29) / 2 g (IEC 60068-2-6)
Power	12/24 VDC, 24 W Absolute Max.
Weight	0.9 kg (1.98 lb)
Size (L × W × H) w/o Lens	216 × 73 × 75 mm (8.5 × 2.9 × 3.0 in)
Mounting	¼"-20 (on three sides), 2 x M4 (on three sides)

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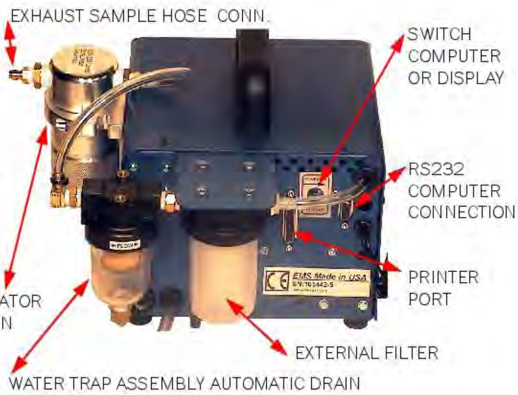
APPENDIX B

EMS Gas Analyser Model 5002 Specification

Use the EMS 5002 as a stand alone or connect to a PC via the serial port, using the optional software to review test results on the screen and print on your printer. Wireless PC interface available.

Use the optional Windows software with a laptop PC, to record data on the road. On your return to the shop, analyze the data in a variety of graphic formats and print the results on your printer.
Heavy duty filter system most reliable in the industry with new water separator.
Easy calibration routine.



Specifications EMS 5002:

- Power: 10 -16 VDC (110/220 VAC 50/60 Hz optional)
- Ranges: HC: 0 - 2000 ppm Low Range
  HC: 0-20,000 ppm High Range
  CO: 0 - 10%
  CO2: 0 - 20%
  O2: 0 - 25%
  NO: 0 - 5000 ppm (Nitric Oxide) *
- Warm up: Less than 5 minutes
- Display resolution: HC: 1 ppm vol.
  CO: 0.01% vol.
  CO2: 0.1% vol.
  O2: 0.01% vol.
  NO: 1ppm*
- Digital display: 3" x 5" LCD Displays all 5 gases, & AFR or LAMDA
- Accuracy (Bar 97 EPA ASM) HC: 4 ppm HC
  CO: 0.02% CO
  CO2: 0.3% CO2
  O2: 0.1% O2
  NO: 25 ppm*
- Drift: Zero and span drift are less than ± 0.6% of full scale for the first hour and less than ± 0.4% of full scale per hour thereafter.
- System response time: Bench: 1.5 Sec/25 ft. hose 5 sec. to 90% of final reading
- Ambient conditions: 35F (2C) to 120F (45C), rel. humidity 0-98%
- Sample hose: 25 feet (7.5 m) with QD coupling /200 F Degrees Max.
- Sample probe: Stainless steel 1200 Degrees F (replaceable flex tip)
- Mass: Approx.: 10 LBS. (4.5 Kg)

Emissions Guide Software FREE w/Analyzer

EMISSIONS SYSTEMS INC.
PO BOX 7086, ALGONQUIN IL. 60102
TEL./FAX : 847-669-8044
E-MAIL: sales@emsgas.com
WEB SITE: www.emsgas.com

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APPENDIX C

USB TC-08 Thermocouple Data Logger general specifications	
Number of channels (single unit)	8
Maximum number of channels (using up to 20 TC-08s)	160
Conversion time	100 ms per thermocouple channel + 100 ms for cold junction compensation (CJC can be disabled if all channels used as voltage inputs)
Temperature accuracy	Sum of ±0.2% of reading and ±0.5 °C
Voltage accuracy	Sum of ±0.2% of reading and ±10 µV
Overvoltage protection	±30 V
Maximum common-mode voltage	±7.5 V
Input impedance	2 MΩ
Input range (voltage)	±70 mV
Resolution	20 bits
Noise-free resolution	16.25 bits
Thermocouple types supported	B, E, J, K, N, R, S, T
Input connectors	Miniature thermocouple

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Minimum	**Processor**: 1 GHz. **Memory**: 512 MB. **Free disk space:** 32–bit: 600 MB, 64–bit: 1.5 GB. **Operating system**: 32– or 64–bit edition of Microsoft Windows XP (SP3), Vista, Windows 7, Windows 8 (not Windows RT) or Windows 10. Beta software: Linux Debian, OpenSUSE and Fedora derived distributions, OS X (Mac). **Ports**: USB 1.1 port.
Recommended	**Processor**: 1 GHz. **Memory**: 512 MB. **Free disk space:** 32–bit: 850 MB, 64–bit: 2 GB. **Operating system**: 32– or 64–bit edition of Microsoft Windows 7, Windows 8 (not Windows RT) or Windows 10. Beta software: Linux Debian, OpenSUSE and Fedora derived distributions, OS X (Mac). **Ports**: USB 1.1 or higher.

Operating temperature	0 to 50 °C

Operating temperature for stated accuracy	20 to 30 °C
Operating humidity	5 to 80 %RH non-condensing
Storage humidity	5 to 95 %RH non-condensing
Water resistance	Not water-resistant

Dimensions	201 x 104 x 34 mm (7.91 x 4.09 x 1.34 in)

PicoLog for Windows	PicoLog data acquisition software can collect up to 1 million samples. Features include: **Multiple views** — view data as a graph, spreadsheet or text **Parameter scaling** — convert raw data into standard engineering units **Math functions** — use mathematical equations to calculate additional parameters **Alarm limits** — program an alert if a parameter goes out of a specified range **IP networking** — transfer measurements via a LAN or over the Internet **Operating systems supported** — Microsoft Windows XP (SP3) to Windows 10. Not Windows RT.
PicoLog languages	**Full support for**: English, Français, Deutsch **Menus and dialogs only for**: Italiano, Español, Svenska
Software Development Kit	Includes example code.
Optional free software	Drivers for Linux and OS X. 32-bit and 64-bit.

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User's guide **Programmer's guide** **Installation guide**	English English English, Français, Deutsch, Italiano, Español, Svenska, Nederlandse, Dansk

Additional hardware (supplied)	USB 2.0 cable, user manuals, software CD-ROM
PC interface	USB 1.1
Power requirements	Powered from USB port
Compliance	European EMC and LVD standards FCC Rules Part 15 Class A
Total satisfaction guarantee	In the event that this product does not fully meet your requirements you can return it for an exchange or refund. To claim, the product must be returned in good condition within 14 days.

Warranty	5 years

TC-08 resolution

B	20 to 1820	150 to 1820	600 to 1820
E	–270 to 910	–270 to 910	–260 to 910
J	–210 to 1200	–210 to 1200	–210 to 1200
K	–270 to 1370	–270 to 1370	–250 to 1370
N	–270 to 1300	–260 to 1300	–230 to 1300
R	–50 to 1760	–50 to 1760	20 to 1760
S	–50 to 1760	–50 to 1760	20 to 1760
T	–270 to 400	–270 to 400	–250 to 400

UTeM
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APPENDIX D

Proton Persona 1.6L 2016 Specification

Specifications

Model		Standard MT	Standard CVT	Executive CVT	Premium CVT
		New Persona			
ENGINE					
Engine Type		1.6L 4 Cylinder DOHC 16V VVT			
Fuel Supply System		MPI (Multi Point Injection)			
Bore & Stroke (mm)		76.0 X 88.0			
Displacement (cc)		1,597			
Compression Ratio		10			
Max. Output	[kW(hp)@rpm]	80 (107) @ 5,750			
Max. Torque	[Nm(kg-m)@rpm]	150 (15.3) @ 4,000			
Fuel Consumption (L/100km)	ECO Drive Assist	5.6	6.1	6.1	6.1
TRANSMISSION					
Transmission Type		5-speed Manual	CVT Automatic		
STEERING					
Gear Type		Rack & Pinion Motion Electric Power Steering			
Steering Adjust		Tilt			
Turning Radius (m)		5.0			
BRAKING					
Front		Ventilated Disc			
Rear		Drum			
SUSPENSION					
Front		MacPherson Strut with Stabilizer Bar			
Rear		Torsion Beam Axle			
Dimensions	Length	4,387			
	Width	1,722			
	Height	1,554			
	Wheelbase	2,555			
Ground Clearance (mm)		155			
Luggage Area (L)		510			
Kerb Weight (kg)		1155	1175	1195	1210
Wheel Size		15"x6.0J			15"x6.5J
Tire Size		185/55 R15			
EXTERIOR					
Front Fog Lamp		-	-	√	√
Rear Fog Lamp		√	√	√	√
Follow Me Home Lamp		-	-	√	√
Auto ON/OFF Headlamp		-	-	-	√
Front Sensor		√	√	√	√
Reverse Sensor		√	√	√	√
Bodykit		-	-	-	*Optional
Rear Spoiler		-	-	√	√
Electric Fold Mirror Housing		-	-	-	Auto
INTERIOR					
Interior Colour		Dual-Tone, Matt Black Finish		Dual-Tone, Titanium Chrome Finish	
Upholstery		Fabric			Leather
Steering Audio Switches		-	-	√	√
Head Unit/Radio Fascia		Single DIN		Double DIN	
Touchscreen Audio System		-	-	-	√
Rear USB Charger		-	-	√	√
Driver Seat Height Adjuster		√	√	√	√
Rear Seat 60:40 Split Folding		-	-	√	√
FEATURES					
Electric Headlamp Levelling		√	√	√	√
Remote Trunk Release		-	-	√	√
Push Start Button		-	-	-	√
Passive Keyless Entry		-	-	-	√
Radio/CD/MP3		√	√	√	√
USB/AUX Jack/Wifi Enabled		√	√	√	√
No. of Speakers		2	2	4	4
Bluetooth Connectivity		√	√	√	√
ECO Drive Assist		√	√	√	√
DVD Player		-	-	-	√
GPS Navigation		-	-	-	√
SAFETY					
ABS with EBD		√	√	√	√
Brake Assist (BA)		√	√	√	√
Electronic Stability Control (ESC)		√	√	√	√
Traction Control (TC)		√	√	√	√
Hill-hold Assist		√	√	√	√
Front Airbags		√	√	√	√
Side Airbags		-	-	-	√
Curtain Airbags		-	-	-	√
ISOFIX & Top Tether		√	√	√	√
Dual Pre-tensioner Seat Belt		√	√	√	√
Immobilizer		With Alarm System			
Reverse Camera		-	-	-	√
EXTERIOR COLOURS					

Graphite Grey | Carnelian Brown | Fire Red | Sterling Silver | Cotton White | Midnight Black

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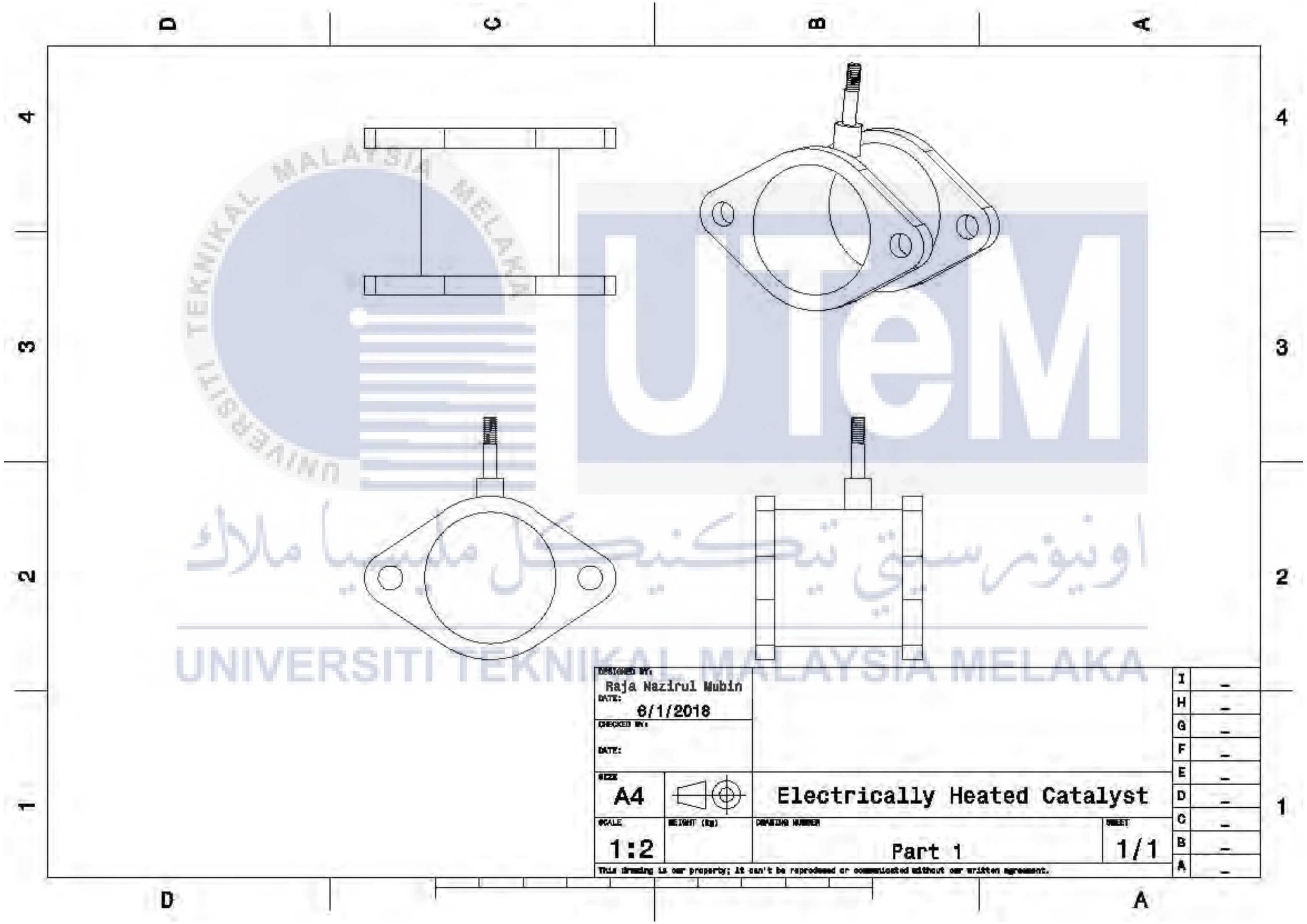
APPENDIX E



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