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BORANG PENGESAHAN
LAPORAN AKHIR PENYELIDIKAN

TAJUK PROJEK : NATURAL GAS MOTORCYCEL
(MOTOSIKAL GAS ASLI)
VOT : 71191

Saya Prof. Madya Dr. Zulkefli Yaacob.
(HURUF BESAR)

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Natural gas Motorcycle
(Motosikal Gas Asli)

Vot: 71191

ABSTRACT

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Air pollution generally comes from emission of mobile and non-mobile sources. Pollution from mobile sources, such as vehicle is dominant in city centers throughout Malaysia. Natural gas is acknowledged as being the mainstream alternative fuel. In Malaysia, pollution is not the only reason to introduce natural gas-powered vehicles but economic is another factor. The country has massive, under exploited natural gas reserve. Natural gas reserve is four times larger than oil reserve. As such, a study has been conducted on bi-fuel motorcycles this is the first program in utilizing natural gas for motorcycles in Malaysia. This research is to study the exhaust emission and performance of motorcycles using natural gas and gasoline.

A set of conversion kit for NGV motorcycles has been designed and installed or creates a workable motorcycle. A set control system has been design to produce a workable motorcycle before the emission and performance tests been carried out. All Exhaust Emission Test and Chassis Dynamometer Test were conducted at MODENAS, Gurun Kedah with Modenas R&D Department.

The performance and emission of a single cylinder fuelled motorcycle with both natural gas and gasoline has been measured. Full load and top gear performance up to 8500 rpm has been covered. The major difference between the two fuels are the exhaust emission from natural gas give a complete combustion which decreases 99.6% of Carbon Monoxide and 72.5% of Unburned Hydrocarbon at a speed of 70km/hr. However, lower calorific value o natural gas and burning velocity, reduces engine power by 15% at high engine speed, without any modification to gasoline engine.

These parameters from the study are very important and useful as guidance to the motorcycle industry using natural gas, a leading technology propelling Malaysia for the next millennium with clean city.

ABSTRAK

Pencemaran udara adalah berasal daripada punca bergerak dan punca statik. Pencemaran punca bergerak daripada kenderaan adalah punca utama di bandaraya-bandaraya Malaysia. Gas asli telah dikenali sebagai bahanapi gantian yang utama dalam usaha mengatasi pencemaran. Di Malaysia, pencemaran udara bukan sebab utama untuk memperkenalkan gas asli untuk kenderaan, malahan ekonomi juga satu sebab yang penting. Negara ini mempunyai banyak simpanan gas asli yang belum diterokai. Simpanan gas asli adalah empat kali banyak daripada simpanan minyak mentah di Malaysia. Oleh demikian, satu kajian telah dijalankan pada motosikal dwi bahan api. Kajian ini adalah kajian penyelidikan yang pertama menggunakan gas asli untuk motosikal. Penyelidikan ini tertumpu pada ekzos emisi dan prestasi motosikal yang menggunakan gas asli. Satu set alat penukaran untuk motosikal gas asli telah direkabentuk dan dipasang ke atas motosikal supaya yang ia boleh berjalan dengan gas asli sebagai bahanapi. Sistem kawalan juga telah direkabentuk sebelum motosikal tersebut dihantar untuk menjalankan ujikaji. Semua ujikaji ekzos emisi dan prestasi dijalankan di MODENAS, Gurun Kedah dengan kerjasama dengan bahagian penyelidikan dan pembangunan syarikat tersebut. Ekzos emisi dan prestasi bagi motosikal yang menggunakan gas asli dan gasoline telah diuji. Prestasi motosikal dengan beban penuh pada gear yang tertinggi telah diuji sehingga 8500 rpm. Perbezaan yang paling besar di antara dua bahanapi yang digunakan adalah motosikal gas asli memberikan pembakaran yang lebih menyeluruh dengan penurunan emisi karbon monoksida sebanyak 99.6% dan 72.5% bagi hidrokarbon yang tidak terbakar. Walau bagaimanapun, gas asli yang mempunyai nilai kalori yang rendah telah mengurangkan kuasa enjin sebanyak 15% pada kelajuan enjin yang tinggi tanpa penubahsuaian enjin motosikal asal. Data-data yang terkumpul daripada penyelidikan in amat penting dan berguna untuk industri motosikal sebagai panduan menghasilkan motosikal yang lebih besih, juga membawa teknologi Malaysia kepada bandaraya yang bersih di dekad yang baru ini.

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These parameters from the study are very important and useful as guidance to the motorcycle industry using natural gas, a leading technology propelling Malaysia for the next millennium with clean city.

CHAPTER 1

INTRODUCTION

1.0 Introduction

Transport ministry of Malaysia has carried out a study on reducing vehicle congestion in densely populated areas and found that Asian countries are usually more densely populated compared to the West.[1] There are about 00,500 and 1000 people per hectare in Malaysia, Singapore and Taiwan respectively. Both the United State and Australia have only 14 people per hectare. One out of five people in Malaysia and one out of two people in Taiwan rides motorcycle because a little space was used for traveling and parking compared to a car. Thus in densely populated Asian countries motorcyclist, cyclist and pedestrian have to use lanes instead of main road to overcome congestion. Motorcycle has become the second major source of mobile air pollution in Malaysia and the government is very pro-active in its attempt to control vehicles' polluting emissions. For instance, Malaysian government try to phase out existing two-stroke motorcycles because it cannot meet the emission standard and emphasis that the new models must comply to emission regulations.

There have been many attempts by the Malaysian government to grapple with solution in air problem through transportation and energy policy. Malaysian Government has taken several actions to support clean fuels such as one used in natural gas vehicle. Such as incentive policies, mandates, financial support for research, development and demonstrations, as well the development of standard for emission control. In 1998 Budget, the government has allocated RM 142 million for tougher enforcement and control measures for conservation of the environment. Stringent enforcement will be implemented on the sources of pollution such as by motor vehicles and industries, where their permitted emission levels are under the Environment Regulations.

Natural gas, which in its natural form is cleaner than gasoline, burns and emits naturally in cleaner way. Thus it will provide the inhabitants of city centers a cleaner environment. This thesis describes the first field experience of converting the first gasoline motorcycle to natural gas motorcycle in Malaysia, together with the results of the test on emission and performance of motorcycle using both fuels.

1.1 Introduction to Project Aims

Malaysians naturally get worked up when misfortune occurs. When it is over, it will be forgotten. Air pollution is a classic example. Every time the air is packed with pollutants and haze, we get excited. We worry about it. We talk about it. We even feel bad about it. But, once the sky is clear, the haze problem will be a by gone to most Malaysians. However, one fact remains, while the is largely attributed to open burning and vehicle emission, it is getting worse and staying over for a longer period each time it occurs. Actually, the fact is getting increasingly polluted and we are going to end up with haze all over the year if no stern action is done.

While the haze is a sad reflection of the health of the planet, its impact on our health may be devastating. Already, there are numerous people waling into pharmacies seeking for cough and asthma medication. There are lots of people with eye and skin allergies as well. Hospitals are getting added o the current number of cough and cold complaints. The occurrence of asthma has shot up, and all this will continue happening until the air pollution is under control.

Vehicles' emission has been identified as the major contributor to local air pollution.

Director of the Department of Environment voted as saying that the emission from the motor vehicles is the major air pollutant source, about 75%. [2]

Transport ministry had carried out a study on ways to reduce vehicle congestion in densely populated areas. In Malaysia one out of five people rides motorcycle and in Taiwan, one out of two people ride in a motorcycle. So, more densely populated Asian countries have been using lanes especially for motorcyclist, cyclist and pedestrian to overcome congestion.

Science, Technology and Environment Ministry through study, found that the two-stroke motorcycles cause more pollution than the four-stroke one due to inefficient combustion process. The minister of mentioned said existing two-stroke motorcycles will be phased out gradually and new models manufactured have to comply with emission regulations in future. [3]

The motorcycle industry is still reluctant to adopt more stringent emission standard, even though motor vehicles are the major source of air pollution. Science, Technology and Environment Minister said, the consultations between the Department Of Environment and the motorcycle industry has resumed two years ago, but the industry is still reluctant to comply to the standard for government decided to phase out existing models gradually. The reason beyond this is the willingness of the industries to spend more money on research and development for improvement of the existing engine.

Emission standards for both petrol and diesel are currently regulated but the gazetting is pending. Local sources of air pollutant grew in 1996, where there were 7.7 million motor vehicles in 1996 compared with 6.8 million in 1995, where the highest vehicle population found n the Federal Territory. As a result, 2.4 million tones of carbon monoxide; 457.9 thousand tones of hydrocarbons; 146.3 thousand tones of oxide of nitrogen and 19000 tones of particulate matter were emitted to the air.[4]

There have been many attempts by government to grapple with solution to the air problem through transportation and energy policy making. Stricter enforcement will be implemented on the sources of pollution such as motor vehicles and industries, which their emission levels permitted are under the Environment Regulations.

Currently, there are many types of natural gas powered vehicle operating throughout the world. Natural Gas is now be acknowledged all over the world as a mainstream alternative fuel. Thus, many cities in the world have voluntarily chosen this cleaner fuel as an alternative.

1.2 Air Pollution and Purpose of Natural gas Motorcycle in Malaysia

According to the environmental report 1996, Vehicles emission has been identified as the major contributor to local air pollution. 8254% of air pollution came from vehicles emission; 8.78% caused by power station and 8.48% caused by industries.[5] In Malaysia motorcycles contribute 32803 tonnes of carbon monoxide and 19696 tonnes of hydrocarbon per year. To reduce air pollution caused by vehicle, Malaysia government supports PETRONAS to introduce Natural Gas Vehicle (NGV) by providing incentives. NGV, which produces much cleaner burning will reduce the emissions of hydrocarbon and carbon monoxide, which is normally produced by gasoline driven cars. However, PETRONAS only introduced NGV system to car and heavy vehicle. Can a motorcycle fuel by natural gas? What happen to motorcycles if the NGV system is installed to it? How can a motorcycle use natural gas as a fuel? What is the emission level of a bi-fuel motorcycle while using cleaner and environment friendly compressed natural gas?

The first project in Malaysia which utilized natural gas for motorcycle was carried out by the Gas Technology Centre NGV Research Group from Universiti Teknologi Malaysia between 30 June 1997 and 28 February 1999. This project is directed towards the study on the conversion aspect of the motorcycle. A set of conversion kit will be developed so that normal gasoline fuelled motorcycle can also run with natural gas

1.3 Scope of study

This study will focus on the development of a workable motorcycle using natural gas and gasoline for 110-cc four-stroke engine. The scope is limited to the development of a set of conversion kit. Four-stroke MODENAS, KRISS 110cc engine with single cylinder is used for this research; since it is a common engine for vehicle and single cylinder is the lowest common demonstration.

CHAPTER II

OVERVIEW OF THE NATURAL GAS VEHICLE

2.0 Overview : NGV

A study by Marchetti and Nakicevoic shows from mathematical projections of statistical parameters that natural gas will be very important energy source for the next century (International Energy Agency, 1991). In fact it will probably be the dominant primary energy source for the next half century. It will replace crude oil as surely as crude has replaced coal and coal replaced wood as the dominant source of energy. This was certainly true in the case of wood, coal and crude oil, especially with inclusion of tar sands and oil shale's. This has not been so widely accepted in the case of natural gas.

Natural gas is an important energy option that is well recognized in certain sectors of many nations' economics, but also largely neglected in others. The greatest potential for becoming self sufficient in energy by increased use of natural gas is in the electrical generation field and transportation. With the distress from acid rain caused by increased SO_x and NO_x in many countries, greater attention should be given to use of natural gas to replace or supplement crude oil and coal products.

2.1 Natural Gas as A Vehicle Fuel

If a country has a largely quantity of natural gas but also has to import crude oil or gasoline to operate motor vehicles then there is an opportunity to substitute natural gas for vehicle fuel. This, of course, depends upon sufficient distribution system being in place. It is difficult for an individual to decide to switch fuels since he is defendant upon an infrastructure being in place to serve him. The motivation for individual or the manger of a fleet to switch will almost always depend upon the personal economic impact. Although he may be pleased to know that his vehicles are emitting less pollution, but he is helping to make his country energy independent. Besides that he may be helping to improve the balance of payment and even that his vehicle may be safer so his prime motivation will still be economics. Does it pay to convert? If the answer is, it takes too long to payoff or it is too inconvenient because of lack of refueling station, then he may tend to stay with the status quo this thinking will almost always prevail eve if mass conversion to natural gas would have enormous benefits to society. So if these societal benefits are important how does a country provide the appropriate motivation to change? The answer is simple, provide incentives. But the execution of sensible comprehensive program is complex.

Table 2.1: Thermal conversion Factors for fuels

Fuel	Joule x 10^6
Bituminous Coal	30.48 per Kg
Anthracite Coal	29.55 per Kg
Wood	30.62 per Kg
Distillate Fuel Oil	38.46 per dm^3
Residual Fuel Oil	41.78 per dm^3
Natural Gas	39.08 per dm^3
Manufactured Gas	20.47 per dm^3

Table 2.2 : Properties hydrocarbon fuels been used in market

Properties	Methane	Diesel	Gasoline	Kerosene
H/C	4	1.63	2.03	1.96
Boiling Point °C	161.5	200+	30.200	150-300
ΔH_{vap} KJ/Kg [a]	510	270	310	300
Q_{gc} MJ/Kg [b]	55.54	43.1	45.80	46.30
Q_{net} MJ/Kg [c]	50.05	40.60	43.80	43.30
Q_{net} MJ/Kg [d]	21.22	37.80	32.41	34.63
Net MJ/Kg Stoic. Mix[e]	2.75	2.73	2.71	2.76
A/F mass [f]	17.24	13.89	15.15	14.71

a = enthalpy of vaporization (kJ/Kg)

b = gross calorific value (MJ/Kg)

c = net calorific value (MJ/Kg)

d = net calorific value (MJ/dm^3)

e = net calorific value in stoichiometric mixture (MJ/Kg)

f = mass stoichiometric air fuel ratio

Table 2.3 : Product of Combustion

Product	Coals	Oil	Natural Gas
Energy per kg of Fuel burnt (MJ)	29	42	53
Quantities For an output of 100 MJ (Kg)			
Fuel needed	34	24	19
C Content	27	20.5	14
H Content	1.7	2.6	5
CO_2 Produced	99	75	51
H_2O Produced	14	21	40

2.2 Introduction of Natural Gas Vehicle (NGV)

Natural Gas Vehicle is using natural gas comprises. This natural comprises is mainly methane. It is the same produce that will be piped in industries and houses when Natural Gas Distribution system makes a pass at a stream. NGV is natural compress under high pressure and stored (still in gaseous form) in a cylinder to provide fuel for the vehicle. NGV is different from LPG (Liquefied Petroleum Gas or Autogas) where LPG comprises mainly butane and propane and is stored as liquid in the vehicle's cylinder. The storage pressure of LPG, 0.689 Mpa is also much lower than NGV pressure 20.7 Mpa. (Tartarini Automotive Italy)

Natural gas is not a new fuel. It has been used to power vehicles throughout the world since 1945 and at present there are approximately one million natural gas vehicles on the road. Countries such as Italy, USSR, New Zealand, USA, Argentina and Canada have already developed successfully NGV program. (Jeff M. Seister, 1996) Today the idea of using NGV as an alternative is better than ever. The technology has developed to the point where NGV can complete with petrol and diesel in almost every aspect. The vehicles that can be converted to NGV are the type of internal combustion engines that account for more than 99% of the automotive engines on the road today. Most of the converted vehicles are still capable of burning their original fuel, petrol or diesel, so they are also called bi fuel vehicles.

A basic natural gas conversion for petrol engine involves the installation of light weight steel cylinder storing NGV at pressure up to 20.7 Mpa (3000 psia) complete with safety interlock and a manual cylinder valve. High pressure gas line carries the compressed natural gas to the regulator where the pressure is reduced from maximum of 200 bar down to just above atmospheric pressure (0.101325 Mpa), as required by the gas-air mixer in the air intake. Then the lower pressure line carries the gas to the gas-air mixer. The air/fuel ratio is set by the manual adjustment of a serial of control valves. As the flame speed of natural gas is much slower than gasoline, the ignition timing must be more advanced for NGV to permit the maximum "mean" effective pressure to be developed in the combustion chamber. While we can advanced the ignition timing from that of the gasoline setting to take advantage of the higher octane fuel and achieve a gain in power output, on bi-fuel vehicles, the limiting factor is the danger of the engine damage by detonation when running under load on gasoline. A pressure transducer on the pressure regulator sends the signal to NGV fuel gauge situated in passenger compartment that indicates the level of contents of storage cylinder. Solenoid valves isolate the petrol or gas line depending whether the engine is running and on the fuel in use by flipping the selector switch.

2.3 NGV Conversion Kits

The conversion kits on a NGV are

1) NGV cylinder with mounting clamps
2) Cylinder valve
3) High-pressure tubing
4) NGV regulator and NGV Shut-off solenoid valve
5) Low-pressure NGV
6) Mixer
7) Gasoline shut-off solenoid
8) Fuel selector switch and NGV gauge
9) Natural gas fill connection
10) Master shut-off valve

These kits are for car and lorry. They will modify to suit motorcycles.

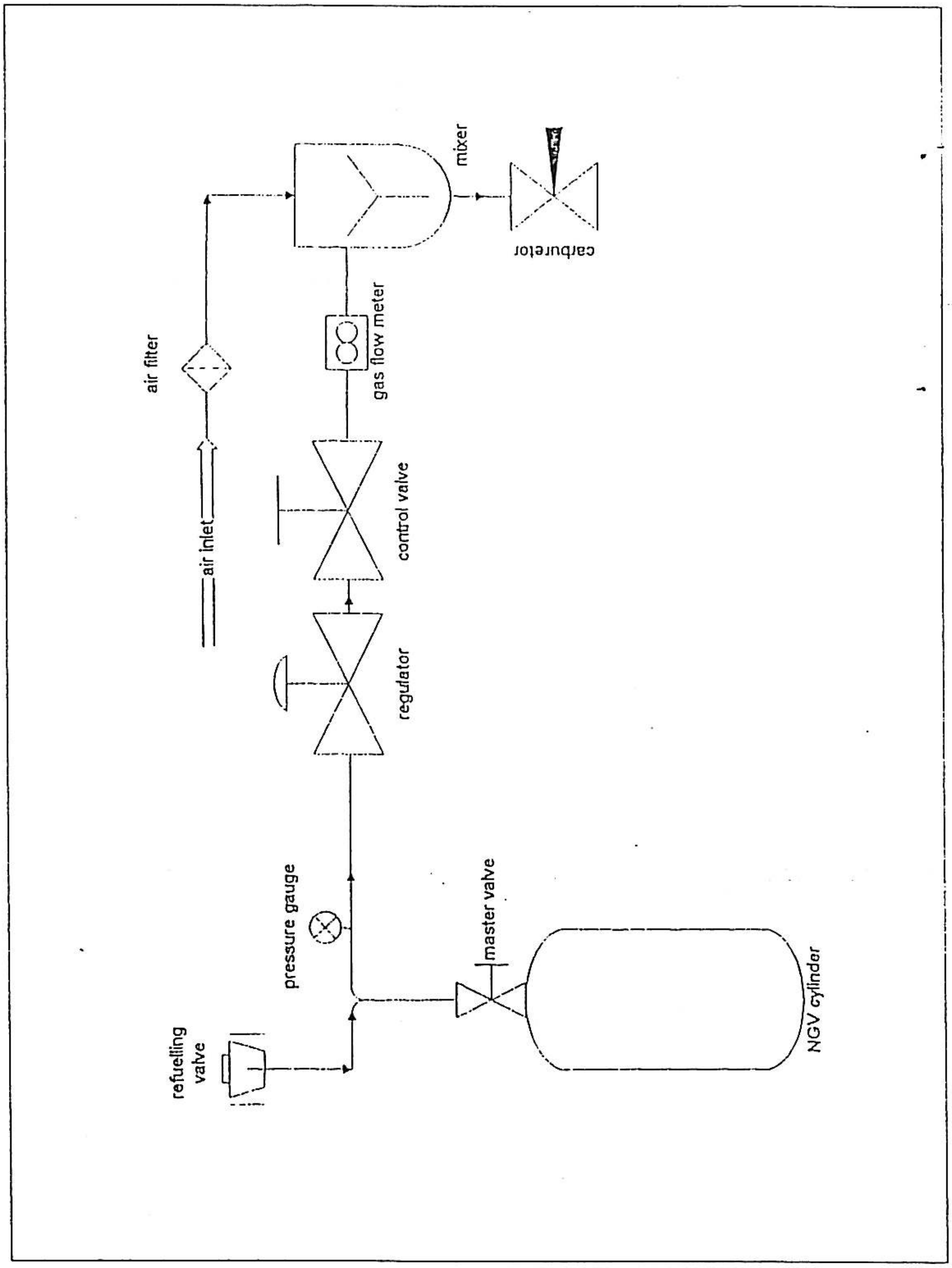

Figure 2.1: Typical diagram of Conversion Kit

Typical NGV Equipment Fitted to a Vehicle

1. STORAGE CYLINDER

   A lightweight steel cylinder storing NGV at Pressure up to 20 Mpa (3000 psig) located in the boot.

2. CYLINDER VALVE

   Safety valve allowing rapid cut-off gas supply.

3. HIGH-PRESSURE GAS LIE

4. ISOLATING VALVE

   Manually operated to turn off gas supply for servicing or emergency.

5. FILLING VALVE

   Probe type-filling valve "Non Return" type to prevent gas leakage.

6. NGV SOLENOID VALVE

   Stop gas supply when engine is not running

7. REGULATOR

   Reduces the gas pressure to atmospheric pressure.

8. NGV FUEL GAUGE

   Located on dashboard, show level of contents of storage cylinder.

9. LOW PRESSURE NGV LINE

10. GAS AIR MIXER

    Connected to the carburetor and controls the gas air mixture.

11. PETROL SOLENOID VALVE

    Stop the petrol flow to carburetor when car is operating on NGV.

2.4 The History of NGV Malaysia and NGV Motorcycle

2.4.1 Natural Gas for Malaysia

With the higher price of gasoline and diesel today, other fuel have being proposed as alternative for vehicles use, example propane gas, solar energy, hydrogen, ,methanol, electric cars and etc. each has its place and benefit in the overall search for ways to reduce exhaust emissions. The only most suitable fuel for any mass conversion besides gasoline and diesel is natural gas.

2.4.2 PETRONAS's Pilot Program

In Malaysia, NGV started being used as a pilot program implemented by PETRONAS in 1986-1988 in Kerteh, Terengganu. The pilot program tested the technical feasibility of using NGV before its commercial introduction. During this program, one NGV dispensing station constructed and 21 PETRONAS Gas Sdn. Bhd's retrofitted to NGV/petrol bi-fuel vehicles use. According to PRSS Deputy director general in his working paper "Clean Fuel Technologies-Research and Development Options", the pilot program produced "very encouraging" result. Therefore PETRONAS decided to introduce this fuel to the public under the Natural Gas for Vehicle Commercial Program. (Petronas, 1996).

2.4.3 PETRONAS's Natural Gas for Vehicles Commercial Program

Learning from the experience of other countries that had successful introduced NGV, PETRONAS then sought and obtain the government's support before embarking on the commercial introduction. As a result, the government provided incentives that sow her dedication to the success of this clean fuel. The incentives include setting of the NGV retail pricing a 50% that of petrol and exempting retrofit kits from import duty and sales tax. At present, retail price of NGV has to be done in phase to tie in with the operation of the Natural Gas Distribution System (NGDS) as it uses the gas drawn from the Peninsular Gas Utilization's (PGU) trunk line. In the initial phases, 7 NGV dispensing stations were installed in 1992, 6 in Klang Valley and 1 in Miri. To cater for the absence of the NGDS in the Klang Valley, the mother/daughter concept was used. The Miri facility is the conventional type. The UMW Corporation Sdn. Bhd. had invested RM8.9 million in the installation of the six dispensing stations in Klang Valley. Used the mother/daughter idea, 7 specially equipped trailers with gas storage cascade are filled at the Shah Alam mother station. Earlier, the incoming gas is metered and regulated. These trailers are then towed and left at daughter station and vehicles are refueled from the storage cylinders. Such practice has been widely used in other countries. NGV is dispensed in litres equivalent of petrol and refueling with NGV ad at the same time. It is due to the NGV dispenser that is located on the same Pump Island as petrol dispenser. In October 1996, other four NGV outlet were operation in Klang Valley using the natural gas from the distribution line from Gas Malaysia Berhad or well known as NGV conventional station. At this stage, there are only three retrofitting workshops available in Malaysia; Two in Klang Valley and one in Miri. (Petronas 1996)

The target for the initial phase is to retrofit 1100 vehicles to bi-fuel NGV/petrol operation by the end of 1994; 900 in Klang Valley and 200 in Miri. As to promote the introduction of this new fuel, PETRONAS offers the special price RM3300 for the conversion includes the complete GV system and all labor charges for the installation, testing and certification.(Petronas 1996)

The response in the Klang Valley was extremely encouraging, especially from the urban taxis. More tan 864 vehicles had been retrofitted and the number is increasing in Klang Valley. So the target of the 900 vehicles was to be achieved easily by the end of 1994. In year 1997, Malaysia has 1114 vehicles using natural gas as a fuel. The good responses have been mainly due to the fuel bill savings that realized by the NGV users. Initial exhaust emission test and performance test would be conducted. (Petronas 1996)

Beyond this initial phase is the wider program that will be implemented again in phases according to the implementation of the NGDS.

The growth in the NGV vehicle-replacing vehicle that would otherwise be using petrol is expected to increase as the following;

Table 2.4: The Expected growth of Light Duty NGV Vehicles in Future

Year	1995	2000	2005
No. of NGV Vehicles	2000	16000	82200
Percentage of total petrol vehicles	0.1	0.7	2.2
Volume of petrol displaced (x 10 liters)	0	83	342

Source: PETRONAS

Table 2.5: The Expected growth of heavy Duty NGV Vehicles in Future

Year	1995	2000	2005
No. of NGV Vehicles	3	2300	10400
Percentage of total petrol vehicles	-	0.3	1
Volume of petrol displaced (x 10 liters)	-	48	250

Source: PETRONAS

2.4.4 Benefits of NGV

The increasing importance in the utilization of NGV is due to many direct and indirect benefits that can be summarized as follows:

a. Clean Burning

b. Better utilization of resources

c. Savings in fuel bill

d. Spin-off industries

e. Longer distance

f. Better safety

g. Cleaner environment

h. Characteristic

2.4.4.1 Clean Burning

The replacements of petrol by natural gas substantially decrease ash and particle levels. For NGV this comes only from lubricating oil that finds its way into the combustion space. The results are cleaner engine, extended lubricating oil life and improvement in spark plug life. So the sharp increases of piston and ring lie can also be expected. (Sam De Maria 1996).

For diesel engines, the main cause of wear is the built up of acidic compounds in the lubricating oil. Diesel fuel contains a substantial amount of sulfur compounds. The high temperature and compression ratio in diesel engines also favor the formation of nitrogen oxides which react with water vapor formed during combustion to produce acids that remain dissolved in lubricating oil. These acids would rapidly corrode vital engine parts if corrosion inhibitors were not added to the lubricating oil to neutralize the acids. Natural gas has extremely low sulfur content and thus provides for longer engine life. (Cole, James and Chiu, 1996)

2.4.4.2 Better Utilization of Resources

At present, Malaysia as 80.8 trillion cubic feet of gas reserves (last for 80 years)compare to 4.28 billion barrels of crude oil that will last for only 19 years. Therefore, the extended use of natural gas in the transportation sector that accounts for 40% of total energy consumed or 54% of total petroleum products consumed would definitely lead to better utilization of Malaysia's resources. (Economic Report 1997/1998).

It is estimated that 0.1 to 0.2 TCF of gas from the pipeline would provide enough natural gas to fuel one million vehicles for a year.

2.4.4.3 Savings in Fuel Bill

The retail price of NGV world-wide at generally 35-65% lower than gasoline or diesel provide savings in fuel bills for the consumer. In Malaysia, NGV is priced at 50% of the petrol price. Currently, the price of the petrol is RM 1.13 per liters and the price of NGV is RM 0.57 per liters equivalent of petrol. As a results the cost of the conversion can be pay back within 6 to 24 months depending on the usage of NGV. (Petronas 1996)

After that the users can enjoy the saving in fuel bill as much as 50% compares to petrol. The maintenance cost of this new kind of vehicle would be lesson for its clean burning as mentioned previously. Besides that, the driver is advised to have a routine check every 10000 km to assure maximum efficiency. Further more the NGV equipment can last longer. The NGV cylinder is designed to withstand the toughest abuse has an expected service life of about 30 years. The engine conversion equipment is expected to last more than 15 years. (Tartarini Automotive SPA)

2.4.4.4 Spin-off Industries

The growth of NGV utilization locally will lead to the development of spin-off industries. Currently all components for the retrofit kits are imported. The potential for the manufacture of the storage tanks especially to cater for the regional market is good.

2.4.4.5 Longer Distance

Since the NGV petrol bi-fuel vehicles can operate on one of the fuels by a switch of fuel selector, the vehicle will travel a longer distance. For example a cylinder 55 liters installed at 1500 c.c. car can travel an average of 190 km before it needs to be refilled. So this bi-fuel vehicles driver will have an advantage of travelling extra mileage compare to other drivers. It becomes an importance as the vehicles use the newly built North-South Highway that allows travelling without a stop for more than 600 km. (Petronas NGV 1996).

2.4.4.6 Better Safety

The claim on better safety for NGV is based on two aspects. Firstly, let us consider the fuel itself. NGV is lighter thab air. If there is any leakage, the gas disperses harmlessly into the atmosphere, unlike the other fuels that will spill on the ground. Petrol and LPG, being heavier than air, hug the grounds and may form puddles if it leaks. In fact, NGV is less explosive than petrol. NGV will not burnt if its proportion in air(fuel/air ratio) is between 1% and 6%. The lower the limit of the fuel's flammability is the most significant factor as far as safety is concerned since in practice 'lean limit' explosion is more probable. NGV vapor disperses much faster than petrol vapour under similar circumstances. It is due to the lower NGV vapour density, which is 0.65, compared to the petrol vapour is 3.5. Also, as this gas is under high pressure, NGV would leak at a very high velocity, aiding greatly in its rapid dispersion. The most important thing is that NGV has a higher ignition temperature (630°C) compared to petrol (450°C), thus a much hotter source is therefore require for ignition. If leakage occurs, natural gas can be easily detected because of its distinctive odor (Hiromi Matsuhura 1996).

Many people think that the NGV cylinder and the fuel delivery system are very dangerous for fear of explosion. In fact the NGV cylinder in the car and the NGV fuel delivery system are totally sealed and the components are far stronger than any petrol tank and petrol fuel delivery system. An impact that would rapture a petrol tank would have little effect on a NGV cylinder. As for NGV cylinder, they are built to withstand extremely high pressure. They are designed, fabricated and tested according to BS5045 Part 11 (UK) or DOT 3AA (USA), for minimum working pressure of 20.7 MPa and minimum test pressure of 30 MPa.

So, it is clear that NGV is even safer than petrol in many aspects. With more than half a million vehicles using natural gas world-wide, independent studies confirm that not a single death or injury has ever occurred as a result of the fuel itself. In an emergency, gas flow can shut by closing the valve on the NGV cylinders or the master shut-off valve located in the engine compartment. Mixed design varies considerably because of the need to fit different vehicles.

Air flows to the mixer from top to bottom before entering the engines. As results of the "Venturi" shape inside the mixer, a negative pressure is produced at the narrowest part. At this point a series of small holes (pan-cake mixer) or from a single pipe, natural gas is sucked /drawn out from the regulator and mix with the air for combustion. These are connected via a "T" valve or power valve to the gas vapour hose from the regulator, which supply gas proportional to the strength of this pressure.

The safety aspects to carry 5 litre equivalent of natural gas, compressed to 20.7 MPa stored in a cylinders in the vehicle trunk, is uppermost in many peoples' mind-it is big, heavy and dangerous. (Tartarini Automotive SPA)

The following articles and reports provide further evidence (Pederson, 1996)

> *"The American Gas Association Monthly, January 1981, reported that although NGV as a vehicle fuel has been used extensively for 30 to 40 years in Italy, no death or injuries have ever been attributed to using it. There are currently over 250000 NGV power vehicles in Italy alone."*

In addition, crash and fire test conducted by Transport Canada in 1982 indicated that natural gas system are more resilient than either gasoline or propane systems. A recent U.S. survey of the major gas-powered fleet vehicles operates, found that in approximately 1300 collisions since 1970, there has never been a fire involving the natural gas system. In more than 180 rear-end collision involving vehicles with storage tanks, the safety record was still perfect. This survey covered more than 2400 vehicles driven nearly 175 million miles. The excellent safety record is at least partially explained by a review of the physical characteristics of natural gas and its system. (Pederson, 1996)

The safety record is further explained by a review of the construction of the storage cylinders.

"The combination of the wall thickness a high strength steel construction results in a cylinder that is probably stronger than any part of the car which it is used"

Crash and fire test conducted in the Netherlands indicated that even at 70 km/hr collisions directly on the pressurized cylinders, the vessels were effectively indestructible. Safety is also inherent in the refueling operation. Refueling with gasoline can produce an explosive mixture of gasoline and air in the gas tank and vehicles area. Natural gas refueling, however is a closed system, explosive mixtures of fuel and air therefore do not develop.

2.4.4.7 Cleaner Environment

In the past few years, the growing concern for the environment quality has given NGV development a tremendous push as NGV is able to provide for a cleaner environment in addition providing all the above benefits.

Car exhaust emission that contain the air pollutant of concern have been reported to contributed to more than 70% of urban pollution. Sin Chew Jit Poh, 13 Sept, 1997) the most significant air quality problems in urban areas are ozone, carbon monoxide, fine particulate matter (PM10), lead and toxic air contaminants vehicle emissions also contribute to regional and global environmental problems emissions of oxide of nitrogen (NO_x) and to lesser extent, oxides of sulfur (SO_x) contribute to regional acid deposition problem. Emission of carbon dioxide (CO), NO_x and hydrocarbons from vehicles contribute to global warning due to the greenhouse effect.

The chemical and physical characteristics of natural gas make are possible to reduce the overall emissions from vehicles using the conventional fuels. The following statements will show us how the NGV acts like a clean fuel.

i) Ozone (O_3)

Ozone is formed by the reaction of oxides of nitrogen with volatile organic compounds (VOC) which is hydrocarbons: aldehydes and alcohol as well as carbon monoxide in the presence of sunlight. It is powerful oxidant, causes eye irritation and aggravations. The formula of reaction is as follow:

$$CO + NOx + HC + O_2 + Sun \longleftrightarrow O_3$$

SUN - Strong Ultraviolet light

Since CO and methane are not conductive to the ozone. The formula above can be simplified as follows:

$$NO_x + VOC\ OR\ NMHC + SUN \longleftrightarrow O_3$$

VOC - Volatile Organic Compounds or NMHC - Non-methane hydrocarbon
Which are more ozone-conductive.

Vehicles using NGV contribute very little to ozone formation compared to the conventional liquid fuel like petrol. Vehicles using liquid fuel emit VOC not only in the exhaust, but also through evaporation, running losses and refueling emissions. For NGV vehicles, only exhaust emissions are significant, as the fuel system is a pressurized close system. Exhaust emissions from NGV vehicles primarily consists methane. So there is only a very little effect on ozone from NGV.

ii) Carbon Monoxide (CO)

CO is e toxic gas formed by the incomplete combustion of fuels. In urban areas almost all the carbon monoxide is from the vehicle emission. The danger of this colorless, odorless gas is that it has more affinity than oxygen for the hemoglobin in our blood. Death occurs at 1000 PPM and at 100 PPM most people suffer headaches, dizziness, lassitude and drowsiness. Generally, it exacerbated heart diseases and compromises brain functions.

NGV vehicles are able to achieve very low CO emissions, almost 90% of the petrol engines because they do not require mixture enrichment for gold starting and operate well on lean mixtures. Cold start CO emissions from NGV vehicles are also unaffected by temperature unlike petrol vehicles. (Pilorusso, 1996)

iii) Particulate Matter (PM)

These are particulate smalls enough to remain suspended in the atmosphere (generally less than 20 micron). Most emission regulation only "respirable" or "dine" particles less than 10 microns in diameter, hence, "PM10". They are due to smoke from heavy-duty diesel engines, lead particles from gasoline vehicles and from engines consuming excessive lubricating oil. Substantial amounts of PM10 are also formed in the atmosphere through the reaction of photochemical oxidants with the oxides of nitrogen and sulfur, significant quantities of which are emitted by heavy-duty diesel vehicles.

Substitution of heavy-duty natural gas engines for diesel in heavy duty trucks and buses would substantially reduce direct particulate emissions, since the only particulate materials emitted by natural gas vehicles is a small amount of lubricating oil.

Heavy-duty natural gas engine can also achieve much lower oxides of sulfur emissions which can be neglected would further reduce PM10 concentrations.

iv) Air Toxic

Substitution of natural gas for petrol and diesel would substantially reduce emissions of toxic air contaminants from motor vehicles. NGV vehicles emit no lead, diesel particulate matter or gasoline vapours; three of the most significant air toxic. In most cities of Malaysia, as much as 90% of the lead in the air come from vehicles. Lead is very toxic, affecting children, especially decreasing their intelligence. Large amounts can cause anemia, kidney failure, permanent brain damage and death and also can increase cancer incidence.

NGV vehicles particulate matter (which consists primarily of vapourized and recondensed lubricating oil) should be much less than those from petrol engines. Since natural gas contains few hydrocarbons with more than three carbon atoms, emissions of benzene and 1.3 butadiene should also be very low and this has been the case in most tests to date. As we can see the widespread use of natural gas instead of the conventional fuels is likely to produce a significant reduction in human damage, including cancer, due to toxic air contaminants.

v) Acid Deposition

Oxides of sulfur and nitrogen emitted to the atmosphere are eventually deposited in downwind areas, in the form of nitrate or sulfate particles or dissolve in rain (or snow). This deposition is responsible for damage to the vulnerable ecosystem due to acidification as well as damage to exposed materials such as metals and stones. NGV contain much lower contents of sulfur than petrol or diesel and so contribute proportionately less SO_x to the atmosphere. NO_x emission from NGV vehicles and can be considerably lower than those from heavy-duty diesels. Overall use of NGV vehicles should reduce the mobile-source contribution to acid deposition.

vi) Global Warming

One concern that is sometimes expressed about NGV vehicle is that the methane emissions might contribute to global warming. Any increase in global warming due to increase in methane emissions from NGV vehicles would be more than offset by a substantial reduction of CO_2 emissions compared to other fuels. Per unit of energy, NGV contains less carbon than any other fossil fuel, and thus produces lower CO_2 emissions per mile, even if the energy efficiency is the same. The improved energy efficiency possible in an optimized NGV vehicle would further increase this advantage. A further reduction in global warming impact would result from the lower CO emissions typical of NGV vehicles.

2.4.4.8 Characteristic

Even if natural gas is in abundant and cheap, it that would not be sold it does not do the job. Natural gas characteristics have octane of 130 versus 110 for propane and 92-98 for gasoline. (see table 2.6). The nature of natural gas as a fuel is better. Since vehicles today will be converted to two-fuel system, natural gas as a fuel is better. Since vehicles today will be converted to two-fuel system, natural gas with a gasoline back up. However for bi-fuel engine, the compression ratio is still set for gasoline the inherent performance benefits is that natural gas is leaner burning, smoother power delivery and lower maintenance costs. Being gaseous, natural gas gives easy cold starting. NGV is non-toxic and is lighter than air. In a case of an accident the gas would simply rise into the air.

The energy density per unit volume of natural gas (regardless of the state in, which latter is stored,) is below than gasoline. In that case, natural gas has greater energy density is sufficient to offset the much greater weight of the storage vessels required by the fuel in its compressed state

Table 2.6: Characteristic Comparison between NGV and Gasoline

Type	Gasoline	NGV
Vapour Density	3.5	0.68
Ignition Temperature (spontaneous)	$430^{O}C$	$700^{O}C$
Octane Rating	96	130
Boiling Point (atmosphere pressure)	$27^{O}C$	$-161^{O}C$
Air-fuel Ratio (weight)	14.5	17.24
Chemical reaction with rubber	Yes	No
Storage Pressure	Atm. Pressure	3000psig
Fuel air mixture quality	Poor	Good
Pollution $CO\text{-}HHC\text{-}NO_x$	High	Very low
Flame Speed meter per second	0.83	0.67

CHAPTER III

ENGINE AND SYSTEM OPERATION

3.0 Introduction

Motorcycle engine is in the category of heat engines. It is also called an internal combustion engine because the fuel, which combined with air, is ignited inside the engine. The heat forms by the combustion cause the gases to expand rapidly inside the cylinder. These expanding gases generate a strong force and push out in all directions with in the cylinder and move the piston. The piston will be pushed away from the centre of combustion. When the piston has moved downwards far as it can go, a port will be opened. Burned gases will escape while the piston returns upward. These burned gases are called exhaust gases, which will come out through the exhaust pipe.

Inertia keeps the crankshaft and flywheel moving in the engine so that the piston will not pause for a long period at the end of its stroke. The piston will return to the top of the cylinder. When the piston reaches the top, it is ready to be forced back down again. Because the piston continues this up and down motion, it is called a reciprocating engine.

3.1 Definition of Engine Parameters

3.1.1 Engine Bore and Stroke

Engine Bore is the diameter across the top of the cylinder. Stroke is the top or bottom movement of the piston. Length of the stroke is the distance traveled by piston from top dead centre (TDC) to bottom dead centre (BDC). When the bore diameter is the same as the stroke, the engine is called square. When the bore diameter is greater than the stroke, it is called over square. When the bore diameter is less than the stroke it is called under square.

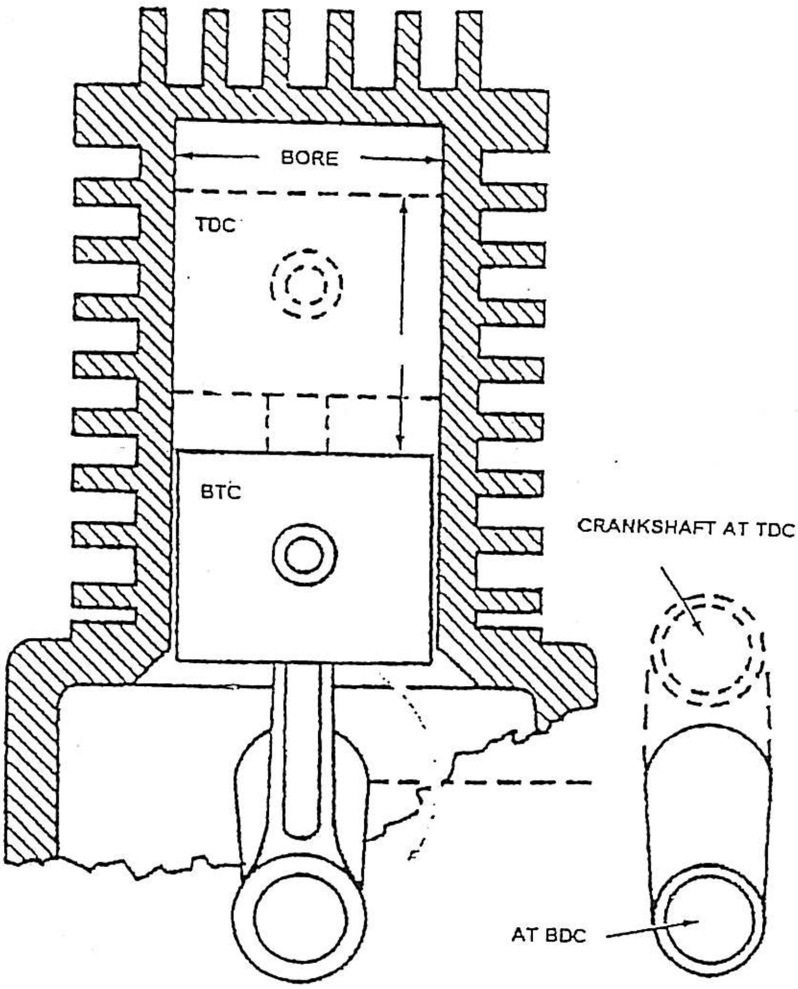

Figure 3.1 : Bore ad Stroke

3.1.2 Engine Displacements

Engine size or displacement, in a single cylinder engine, refers to the total volume of space increases the cylinder as the piston moves from the top to the bottom of its stroke.

To work out a given engine's displacement, first determine the circular area of the cylinder (0.7854 by diameter^2). Then multiply that answer by the total length of the stroke (piston travel). The formula is:

$$\text{ENGINE DISPLACEMENT} \quad 0.7854 \times D^2 \times \text{LENGTH OF STROKE}$$

3.1.3 Compression Ratio

The compression ratio of an engine is a measurement of the relationship between the total cylinder volume when the piston is at the bottom of its stroke as compared to the volume remaining when the piston is at TDC.

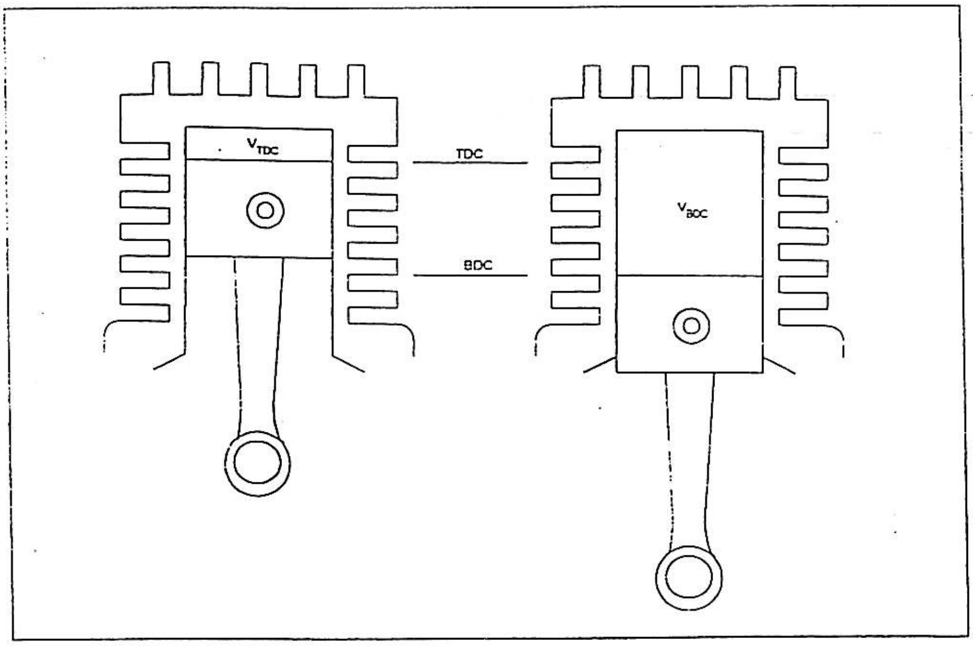

Figure 3.2 : Volume of cylinder at TDC and BTC

3.1.4 Force

Forces are being applied all around us. Force is the pushing or pulling of one body on another. Usually two bodies must be in contact so that force can be transmitted. Many forces interact when the engine is operating. Rotational speeds of the crankshaft and flywheel create centrifugal force, which causes tensile stress within the material which make up this parts. One of the force uses well in engine is the one being applied to the top of the piston by the rapidly expanding gases. The greater the force applied to the piston, the greater the amount of power and work that can be done by the engine.

FORCE = PRESSURE x AREA

3.1.5 Work

Work is accomplished only when a force is applied through a distance. The amount of work is the product or result of the force and the distance through which it is moved.

WORK = FORCE x DICTANCE

3.1.6 Power

In studying the formula for work, note that it does not consider the time required for doing the work. Power is the rate at which work is performed.

The formula for power is :

POWER = WORK / TIME

Work is a force applied to an object causing the object to move and power is the rate of getting the work done.

3.1.7 Engine Power

Engine power, indicates the actual usable power delivered at the engine crankshaft. Engine power is not always the same. It increases with the engine speed. At a very high and generally unusable engine speed, the engine power output will drop off somewhat.

Engine power can be measured by using an engine dynamometer. To check the engine power, the engine under test has to be operated with the throttle wide open. The engine speed is reducing to a specific number of revolutions per minute tightening the pressure arm on the flywheel. The dynamometer usually uses eddy current brake as its loading system.

3.2 Motorcycle: Four Strokes

A gasoline or natural gas fueled engine is a mechanism designed to transform the chemical energy of burning fuel into mechanical energy. Motorcycle engine is an internal combustion engine. The gasoline or natural gas is combined with air and burned inside the engine.

A four strokes motorcycle engine requires four strokes per cycle to complete one operating power cycle. A stroke of a piston is a piston's movement in the cylinder from one end to the other end. Each stroke of the piston is the either moving toward the rotating crankshaft or getting away from it. And each stroke is identified by the job that it performs.

For four-stroke engine, these strokes are termed; intake, compression, power and exhaust. Two strokes occur during each revolution of the crankshaft. Therefore, a four-stroke cycle requires two revolutions of the crankshaft.

3.2.1 Intake Stroke

The piston travels downward in the cylinder on intake strokes. As the piston moves down, the volume of space above it will increase. These create a partial vacuum that sucks the air-fuel mixture through intake valve port into the cylinder. With the nature balancing unequal pressures will force the air through the carburetor. This gives a large boost to the air-fuel induction process.

3.2.2 Compression Strokes

The compression stroke is created by the piston moving upward in the cylinder. Compression is a squeezing action while both valves are closed. On this stroke, the valves are tightly sealed and the piston rings are used to prevent leakage past the piston. The air fuel mixture is compressed into a smaller space and increases the force of combustion.

a. When atoms that make up tiny molecules of air and fuel are squeezed closer together, heat energy is created. Each molecules of fuel is heated very close to its flash point (point at which fuel will ignite spontaneously). When combustion occur, it is practically instantaneous and complete for entire air fuel mixture.

b. Force of combustion is increased because tightly packed molecules are highly activated and are striving to move part. This energy combined with expanding energy of combustion provides tremendous force against piston.

3.2.3 Power Stroke

During the power, both valves remain in the closed position. As the piston compresses the charges and reaches the top of the cylinder, an electrical spark jumps the gap between the electrodes of the spark plug. This ignites the air fuel mixture and the force of the explosion forces the piston downward. The flame progress outward from the spark plug, spreading combustion and providing a continuous and even pressure over the piston ace throughout the power stroke.

The entire fuel charge must be ignite and expended during an incredibly short time. Most engines have the spark to ignite the fuel slightly before the piston reaches top dead centre of the compression stroke. This provides a little more time for the mixture to burn and accumulates its expending force.

The amount of power produced by the power stroke depends on the volume of the air fuel mixture in the cylinder and the compression ratio of the engine (proportionate difference in volume of cylinder and combustion chamber at bottom dead centre and top dead centre). When the compression ratio is too high, the fuel may be heated to its flash point and ignites too early.

3.2.4 Exhaust Stroke

The exhaust valve open and the rising piston pushes the exhaust gases from the cylinder. It must allow a streamlined flow of exhaust gases out through the port. The heat absorb by the exhaust valve must be controlled or the valve will deteriorate rapidly. Some valve heat is carried away by conduction through the valve stem to the guide. However, the valve head, which is the hottest part of the valve, transfer heats through the seat to the cylinder block.

3.2.5 Valve Timing

The degree at which the valves open or close or after the piston is at the top dead centre or bottom dead centre varies with different engines. However, if the timing marks on the crankshaft and camshaft gear are aligned, the valve timing will take care of itself.

3.2.6 Octane Rating

The octane rating for the natural gas is about 130, meaning that engines could operate compression ratio of up to 16:1 without "knock" or detonation. Such a compression ratio would result in higher mileage and power improvement of 25% to 40% over that of today's low compression engines. (Tartarini Automotive) For bi-fuel engines have to be able to operate on both NGV and gasoline which limiting the compression ratios to between 7.5:1 to 9.5:1, depending on the grade of the gasoline used. Using NGV at such low compression ratio results in combustion chamber temperature well below the ignition temperature required for combustion.

This combined with the fact that natural gas vapour is an insulator compared to atomized gasoline, means that the healthy spark is required to induce combustion. Electronics ignition systems are able to provide sufficient spark energy for NGV use. Consequently, it is suggested that the spark plugs, high-tension wires and condenser will have to be kept in good condition in order to maintain the required spark energy.

3.2.7 Power Output

Natural gas has a mixture with a calorific value slightly lower than gasoline and that results in a minor performance loss. The maximum power obtainable from the power stroke depends in part upon the amount of oxygen in the mixture to support the combustion of the fuel. A dry gas fuel, such as natural gas, occupies a greater volume than a liquid for the same energy content. In simple terms, this means that the energy content of the charge mixture is less with natural gas than gasoline.

A minor loss of the power could also be cause by slower flame speed of natural gas, thus causing burning to continue through part of the power stroke. Some of the loss can be recovered automatically advancing ignition timing. Vehicle operation is not greatly affected unless it is required to run for long periods at near full power and speed.

3.2.8 Ignition Timing

As the flame speed of the natural gas is much slower than gasoline, the ignition time must be more advance for NNGV to permit the maximum "mean" effective pressure to be developed in the combustion chamber. While we can advance the ignition timing from that of the gasoline setting to take advantage of the higher octane fuel and achieve a gain in power output, on bi-fuel vehicles, the limiting factor is the danger of the engine damage by detonation when running under load of gasoline.

Most bi-fuel equipment manufacturer left the ignition timing to be as for gasoline engine setting and to leave the vacuum advance unit connected. Advancement from the standard ignition timing setting can be made if the power loss on NGV is unacceptable. However, limit the advance to a point below that where detonation occurs when running on gasoline.

Electronic spark advance devices are available for bi-fuel vehicle that will produce an unaltered spark on gasoline operation and an advance spark suitable for operation on natural gas.

3.3 Fuel System.

Fuel system in motorcycle is important as the lifeline of the vehicle because power is Proportional to airflow relies on the assumption that the optimum amount of fuel can be introduced to the air and be successfully burnt. The amount of fuel is varying with operating conditions.

Optimum means an air-to-fuel ratio of about 12:1 (10:1 for natural gas) by weight when fuel power is required, dropping to about 18:1 (20:1 for natural gas) for maximum economy for gasoline fuel. The engine also needs a very rich mixture for starting and idling, with extra richness to cope with transient conditions like sudden acceleration. Actually the engine does not need the rich mixture but in these borderline condition it is the only way to ensure that something like the right mixture arrives inside the cylinder. For gasoline fuel, all of the air will get there but some of the fuel will be lost, dropping out of the airflow and forming the liquid layer on the sides of the intake tract. In steady conditions, this would soon evaporate and the rate of evaporation would equal the rate of dropout. But in transient conditions such as starting or accelerating there is not the time available to reach the steady state.

In gasoline fuel system, the fuel should ideally be presented in a form which makes it possible to get complete combustion-that is, the fuel must be broken into tiny droplets (atomized) and evenly distributed throughout the air. Otherwise the fuel will not be burnt in the short time available between ignition and TDC. The fact that this process is not totally efficient is demonstrated by the need to use an air/fuel ratio of 12:1, while the chemical balance for total combustion atomization process would happen because natural gas is in gas phase.

From this it is possible to see that there are three mixture conditions, other than perfect. There are rich (less than 12:1), weak (In excess of 14:1) and 'wet'- in which the fuel is not sufficiently atomized for full combustion. Definitions of richness, etc, can be deceptive. For example in a rich mixture you would expect unburned fuel to be found in the exhaust, while a weak mixture would leave oxygen in the exhaust. Unfortunately, a wet mixture will give both of these symptoms, regardless of the proportions of fuel and air flowing from the carburetor. Consequently, it is necessary to measure the fuel flow and relate it to power produced. This result is the fuel flow (in lb/h or pt/h) divided by the power (in bhp) and is known as the specific fuel consumption (SFC) and is measured in units of lb/h or pt/h. the equivalent in ISO units is gm/kW-h

This is a kind of measure of efficiency- what you pay for divided by what you get- and therefore the smaller the number you get the better it is. Experience shows that the optimum value is around 0.50 to 0.55 for most four-strokes. (John Robinson, 1994). Below this the mixture strength is weak and the gas temperature goes up, locally enough to to overheat valves or piston crowns. At a value of around 0.3to 0.4 lb/pt-h the mixture will be so weak that the engine will misfire, similarly, a rich mixture will cause misfiring in the region of 0.80 lb/pt-h. The actual values will depend on the efficiency of the carburetor as an atomizer and of the combustion chamber design.

Fuel flow measurement is usually made by putting a flow meter in the supply to the carburetor(s), in which case it is important to check that the measured fuel is reaching the engine and is not being lost through carburetor flooding or through being sprayed back from the carburetor bellmouth.

The Specific Fuel Consumption (SCF) figure makes a useful comparator during engine development, as it can point out restrictions in the engine oftenly. If, for example, the engine speed is increased and both the fuel flow and dynamometer loads go up, then the airflow must have increased and all is well. If the speed and fuel flow increase but the load does not, then SCF suggests a restriction in airflow, upstream of the carburetor. If the speed goes up but the load and fuel flow do not, then the restriction is downstream of the carburetor.

The process for finding the ideal mixture strength involves running the engine at constant speed and throttle, and monitoring the load while the fuel flow is progressively decrease (by changing the appropriate jet, needle, etc). the resulting chart of fuel flow versus load or power is called a mixture loop and from it the optimum setting for power or economy can be seen.

Table 3.1: Mixture loop at constant speed and constant throttle.

Main Jet	Fuel Flow	Power	SCF
	Pt/h	(bhp)	pt/hp-h
Largest	49.5	66	0.750 rich misfire
	43.0	68	0.635
	36.6	69	0.530 optimum
	30.1	68	0.443
	22.6	66	0.342
Smallest	18.3	63	0.290 weak misfire

A slightly rich mixture is the easiest to ignite the fuel burns quickly initially because the drops of fuels are packed more densely and the voltage requirement at the spark plug is lower than for a stoichiometric or even maximum power mixture. Of course, towards the end of the combustion it would be less efficient because there would be an excess of fuel and not enough oxygen. So the best all-round mixture would be one tat was slightly rich near the spark plug and had excess air at the further reaches. This is called a stratified charge.

3.4 Lubricating Oil

What engine oil must do? Engine oils have several functions. Here are four of the most important:

a. Oil reduces friction. Wear scuffing and scoring is caused by metal to metal contact of moving parts. Wear can be also result from acid corrosion, rusting and from the abrasion of contaminates carried in the oil. To prevent metal to metal contact the oil must maintain enough viscosity or thickness to provide a film or cushion between the moving parts under all operating temperature. In spite of high internal heat, the viscosity must be no higher than necessary to give a good starting and yet provide the least friction under sustained running.

b. Oil cool moving part. Engine oil is largely responsible for piston cooling. This is done by direct heat transfer through the oil film to the cylinder walls and on to the cooling system and by carrying heat from the underside of the piston crown and skirt to the engine crankcase. Oil of equal viscosities have the some heat conductivity to resist decomposition when in contact with the surface.

c. Oils help to seal the cylinder during the combustion. Pressure in the cylinder may be 1000 psi or higher. Oils help the piston ring to seal the cylinder, pressures the cylinder by forming an oil film on the piston and cylinder wall.

d. Oil keeps the part clean. Contrary to popular opinion, engine oils do "wear out". Extended service not only depletes the additives, but also oxidized the base oils to harmful compounds. While good filtration extending the life span of engine oil, many contaminate are soluble in the oil and will pass through the filter. This contaminates are primarily unburned to partially unburned fuel, but corrosive acid and water are frequently present.

The oil must prevent the formation of these materials or once formed, keep them in suspension so they do not settle inside the engine. If engine oil is to fulfill all these requirements, the oil must do the following:

i. Keep a protective oil film on moving part
ii. Resist corrosion and rusting.
iii. Resist high temperature
iv. Prevent ring sticking
v. Prevent sludge formation
vi. Flow easily at low temperature
vii. Resist foaming
viii. Resist break down after prolongs use.

CHAPTER IV

NGV CONVERSION KIT

4.0 Introduction

A gasoline vehicle to use natural gas as a fuel, it need a set of component. This set component is called as Natural Gas or Vehicle (NGV) Conversion Kit. The natural gas is stored at pressure up to 3000 psi in one or more cylinder bolted to the vehicle. From cylinder, by means of fuel pipe the natural gas will be conveyed to regulator, where its pressure is reduced to near/below atmospheric pressure, and directed to the mixer natural gas and air will mix before go to combustion chamber. This means that a gasoline vehicle needs another fuel system to store and supply the natural gas for that vehicle running with natural gas.

4.1 NGV Conversion Kit

4.1.1 NGV Cylinder with Mounting Clamps

Cylinder use for natural gas is made of strong high-strength steel. They are built to withstand greater impact than propane or gasoline tanks. The cylinders are rugged and built to exacting standard standards. Each is equipped with a pressure relief device and shut of valve for maximum safety.

Cylinder manufactured according to the Italian specification represents the best that is currently produced for the CNG field. (Faber Industries SPA). They are accepted in all countries of South America, Asia and Africa beside New Zealand and Australia. Cylinder made to other European specifications (e.g. Germany, France and Holland) differs because of higher weight (10-12 % more)

NGV cylinders manufactured to special permits for North America have a lighter weight compared to the industrial ones. This is subordinated to the control of maximum impurities, level contained in the natural gas, which may be responsible for corrosion phenomena. Every user must be aware of these limits to the use of the cylinders.

High-pressure cylinder may be potentially dangerous if used without care or attention. It is suggested that any person using them completely acquainted with norms issued in the proper country.

NGV cylinder needs specially designed clamps for mounting it. They are mounted to a rigid steel framework, which is in turn bolted to the vehicle. (Faber Industries SPA).

4.1.2 Cylinder Valve

Cylinder valve is a manual shutoff valve mounted to the cylinder. It has a burst disc installed to guard again explosion risk in fire. Flexible hoses are used to vent the leaked gas (if any) to the underneath of the vehicle boot or protection cover (motorcycle)

4.1.3 High Pressure Tubing

Fuel lies running between the storage cylinder and the pressure regulator are made of high strength steel. Piping shall comply with AS1835 or AS1836. They are usually along the flame of the vehicle for better protection.

4.1.4 NGV Regulator and NGV Shut-off Solenoid Valve

The NGV regulator assembly reduces the pressure of the stored gas draw from the cylinders and regulates the flow to the air-fuel mixer, which is installed before carburetor. The gas flow rate from regulator varies according to te negative pressure from the mixer.

The NGV shut-off solenoid valve shuts off the high-pressure gas supply when the engine is turned off or stalled.

4.1.5 Low Pressure NGV Hose to Carburetor

This hose is connected between the regulator ad the mixer. Low pressure gas flows through this hose to the mixer.

4.1.6 Mixer

The air-fuel mixer delivers to correct ratio of natural gas to air for combustion. The mixer is the type of venturi device, which operate o the throttle control valve ad meters the proper quality of natural gas into the air stream over the full range of engine airflow demand. Gas enters the mixer through a nozzle where it mixes with the air pass through the veturi system and entering the engine.

4.1.7 Gasoline Shut-off Solenoid Valve

This solenoid shut-off the flow of gasoline when natural gas supply is being used. The gasoline solenoid s fitted in the gasoline supply line between the fuel filter and the carburetor. When the vehicle operates the natural gas, this valve closes, stopping the gasoline flow to the carburetor

4.1.8 Fuel Selector Switch ad NGV Fuel Gauge

This switch is installed at a place, which can be easily reached of. Switching back ad forth between natural gas ad gasoline ca be done without stopping the vehicle to turning off the engine.

The switch is the three-way rocker switch, which select gasoline operation, natural gas operation, or both fuels switched off. It is necessary when switching from gasoline to natural gas to have both fuels off to allow the gasoline line to be emptied completely before switching to natural gas operation.

The NGV fuel gauge (pressure gas) is installed and this gauge monitors the amount of natural gases I the storage cylinder.

4.1.9 Natural Gas Fill Connection

A probe type-filling valve is fitted. The valve accepts the probe filling nozzle. It is fitted with a o-return valve to prevent loss of gas from the vehicle. When it is not used, a dust plug is fitted I the probe receptacle to prevent foreign matter entering the valve.

4.1.10 Master Shut-off Valve

This valve has a quick acting action enable the NGV supply to be shut off in the engine compartment in a emergency.

4.2 Design Consideration

The installation of compressed natural gas fuel system I internal combustion engine must in accordance with the code of practice MS1096 by the department of Standard Malaysia. The design, construction and installation for the natural conversion kit must fulfil the standard requirement. Road Transport and Department of Safety and Health, Ministry of Human Resource should approved all the equipment and system used I the natural gas fuel system before the vehicle ca run on the road.

4.3 Standard and Specifications

4.3.1 Cylinder

Cylinder for compressed natural gas shall be designed, fabricated and tested in accordance to New Zealand Standards, NZS 5454-Lightweight Steel Automotive compressed natural gas cylinders for use I New Zealand. The cylinder shall be lightweight and safe because the weight of the cylinder will be affect the vehicle tare weight ad manufacturer's rating axle loading should be considered.

4.3.1.1 Cylinder Surface Treatment

All steel cylinders other than stainless steel shall be protected against external corrosion by application of heat reflecting corrosion inhibiting paint. Before the cylinder is used, the cylinder surface shall be adequately prepared by power too I cleaning. A base coat, alkyd primer shall be used for all steel cylinder. For externally mounted cylinders a finish coast giving protection against impact damage such as chlorinated rubber shall be used.

4.3.1.2 Cylinder Marking

According to MS1096, each cylinder shall be permanently ad clearly marked on a thickened portion of the cylinder. The following information must marked at the cylinder:

a. The specification of the cylinder
b. The manufacture's name and serial number of the cylinder
c. The name of inspection authority and date of cylinder inspection
d. The cylinder test pressure
e. The design charging pressure at 15oC
f. The nominal water capacity of the cylinder
g. The tare weight of the cylinder

4.3.1.3 Fitting and Filling Connection

Each cylinder shall have a shut-off valve mounted directly on it. This valve must be designed for cylinder working pressure and test pressure. As requirement of Australian Standard, AS2473- Valves for compressed gas cylinder, the cylinder valve must have a burst pressure of not less tan 70 MPa and capable to shut-off the gas supply to fuel system. The burst disc backed by fusible alloy, which is to have a nominal melting temperature of 100°C. Cylinder valve shall be provided with an outlet thread of ¼ inch NPT or other thread approved by the Statutory Authority..

4.3.1.4 Compressed Natural Gas (CNG) Fuel Line

Compressed Natural Gas Fuel Line working pressure is exceeding 2.15 MPa, which shall be steel piping approved use with compressed natural gas. A burst pressure test should be carrying out for piping at 70 MPa and it must be effectively protected against corrosion. Piping for CNG shall have an outside diameter not greater tan 8 mm. (MS1096: 1997)

Flexible hose use I CNG shall comply with Standard of Society of Automotive engineers, SAE 100R1. Each flexible hose assembly shall marked with the manufacturer's name and trademark, type, size ad working pressure. This hose shall be located as far away as practicable from the exhaust system and it shall not be closer than 100mm.(MS1096: 1997)

4.3 Natural Gas Motorcycle Conversion Kit

This is the first time for motorcycle using the natural gas as fuel. The first conversion kit for the motorcycle was included:

a. 55 liters CNG Cylinder

b. Refueling Valve

c. Pressure Gauge

d. Two Stage Regulator

e. Mixer

f. Fuel Control System

The Conversion kit has been set up on a board

CHAPTER V

METODOLOGY

5.0 Introduction

To test engine is subjected to an extensive pre-conversion test check in order to meet the manufacturer specification ad their "state of tune" is assessed according to the equipment supplier instructions. The test on the engine dynamometer is conducted at steady-state conditions over the load and speed ranges of the engines based on the power and exhaust gas emission for both gasoline and natural gas modes.

This study is divided into two phases. Firstly a workable motorcycle has been designed with natural gas conversion kit. The approximate gas flow has been initially identified. These test were conducted at Makmal Sistem Gas FKKKSA, Universiti Teknologi Malaysia using an alternator power system to measure power output from the motorcycle engine based on engine dynamometer system.

In addition to the test in Universiti Teknologi Malaysia a second phase has been conducted at Research & Development Laboratory at MODENAS, Gurun Kedah. The exhaust emission and performance tests have been carried out at MODENAS using Chassis dynamometer.

5.1 Test Rig

5.1.1 Natural Gas Motorcycle Conversion Kit

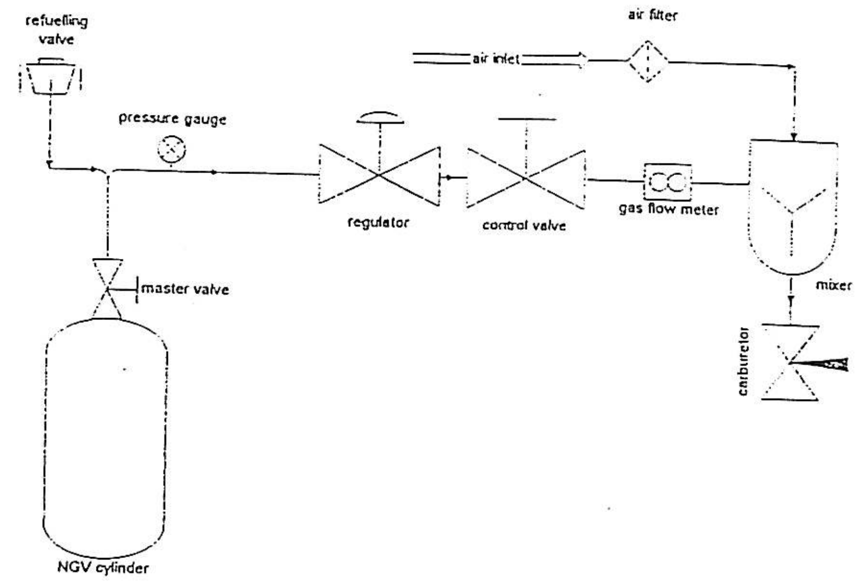

Figure 5.1 Natural Gas Conversion Kits

NGV conversion kit has been set-up to a board for the testing. Those conversion kit include one 55 water capacity cylinder wit the master valve. A rapture disc was build-in at the master valve and refueling connection was fitted to it. The compressed natural gas is supplied to 2 stages regulator in order to regulate the gas from high pressure (3000 psig) to low pressure (5 psig) before entering the mixer.

5.1.1.1 Mixer

Mixer system is designed to be mounted on the carburetor adapter and do not alter the external appearance or operation of the air filter assembly. In this study, the mixer was based on Proton Saga Car NGV Mixer design. Mixer inlet connection dimension is designed to fit into air filter and outlet connection is designed as same size with carburetor. This is due to the bi-fuel system so that the installation will not a effect the gasoline fuel system. The mixer is a venturi device, with generates turbulence flow for well-mixed air and fuel. Beside that, the mixer also generates a low-pressure of air and fuel is proportionate to the engine fuel demand.

From Bernoullli's equation,

$$P_2 = [\,1/2\rho\,(V_2^2 - V_1^2)\,)] \; - \; P_1$$

Where,

V = Velocity of flow

P = Pressure of fluid

ρ = Density of fluid

1 = Section at mixer inlet

2 = Section at mixer outlet

So,

The velocities are found from the known flow rate,

$$Q = Q\ \text{air} + Q\ \text{fuel}$$

The mixer system is designed based on air/fuel ratio of 10:1 (vol/vol.fuel) wit a maximum fuel flow rate of 24 liter per minute (lpm)

$$Q = (10 \times 24)\ lpm + 24\ lpm$$
$$= 264\ lpm$$
$$= 0.041\ m^3/s$$

$$V_2 = Q/A_2$$
$$= 0.0041\ /\ ((\pi/4)\,(0.026)^2)$$
$$= 7.722\ ms$$

$$V_2 = Q/A_2$$
$$= 0.0041\ /\ ((\pi/4)\,(0.046)^2)$$
$$= 2.467\ ms$$

since P_1 is open to atmosphere so P_1 is assume to be 1 atm or 1.0133×10^5 Pa.

$$\rho = \rho\ air\ (10/11) + \rho\ fuel\ (1/11)$$
$$= 1.17\ kg/m^3\ (10/11) + 0.7404\ kg/m^3\ (1/11)$$
$$= 1.13\ kg/m^3$$

$$P_2 = 1/2\rho\,(V_2^2 - V_2^2) - P_1$$
$$= ½\,(1.13)(7.722)^2 - (2.647)^2) - 1.0133 \times 10^5$$
$$= -1.0130 \times 10^5\ Pa$$
$$= -0.9997\ \text{atm (negative pressure for suction)}$$

Reynolds number,

$$Re = DV\rho / \mu$$

Assume the fluid is air at 28°C, $\mu = 1.85 \times 10^{-5}\ N.s/m^2$

$$Re = 0.046\,(2.467)(1.13) / 1.85 \times 10^{-5}$$
$$= 6931.6\ \text{(Re>4000, the flow is turbulent)}$$

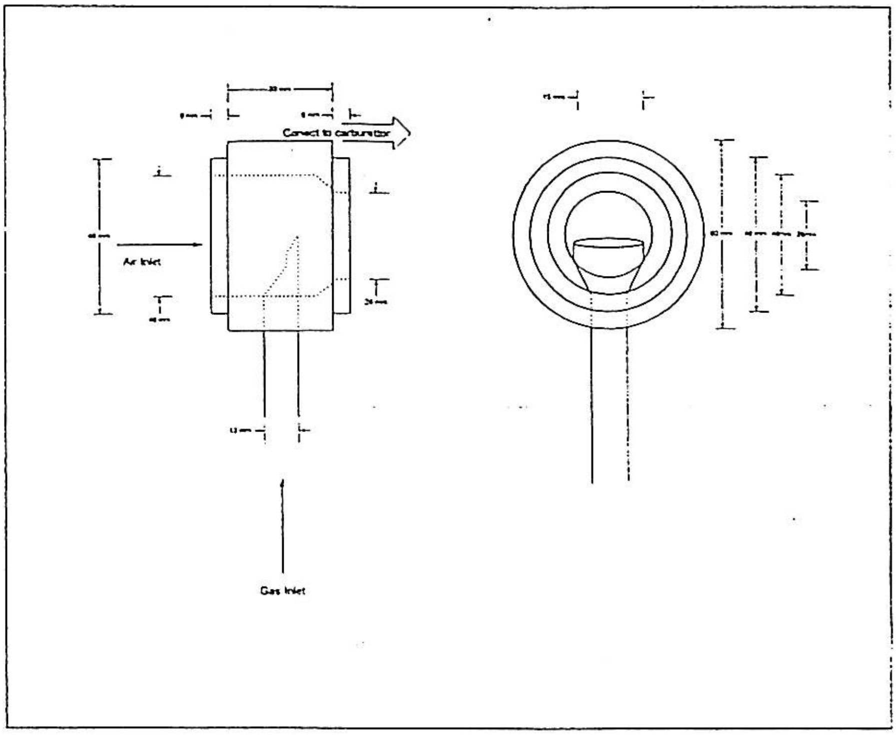

Figure 5.2 : Mixer

5.1.1.2 Cylinder

I this test rig, a 55 liters water capacity cylinder was installed. This cylinder is design for NGV vehicle which fulfil the standard NZS 5454.

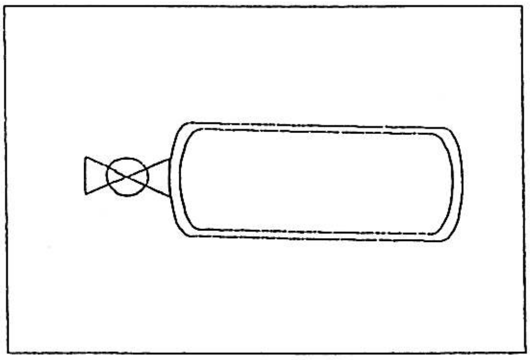

Figure 5.3 : Cylinder with master valve

5.1.1.3 Regulator

The basis function of any gas regulator is to match the flow of gas through the regulator to the demand for gas placed upon the system. At the same time, the regulator must maintain the system pressure within certain acceptable limits. However the expansion of the gas produces the cooling effect or Joule Thompson effect. As a general rule, the reduction of pressure through a gas regulator will cause six or seven degrees of temperature reduction for every 100 pounds of gas (Fisher, Regulator Handbook). When a gas flows through a restriction without any appreciable change in kinetic energy, the primary result of the process is a pressure drop as a function of the regulator. For ideal gases a moderate condition of temperature and pressure, a reduction in pressure at constant enthalpy results in a decrease in temperature.

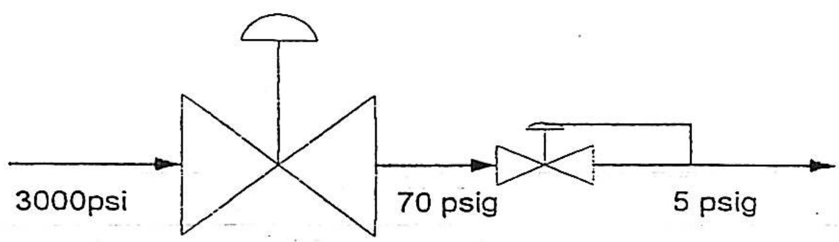

Figure 5.4: 2 Stages Regulator System

For tis project, a multistage pressure regulator has been fitted o a testing rig to regulate the pressure from high pressure (3000 psig) to low pressure (5 psig). Natural gas from 3000 psig with temperature 28°C will be regulated to 70 psig at steady state using a first stage regulator. However, te temperature will decrease to –99.25°C. Calculation of temperature drop as below:

Assume the process at constant entalphy. (J.P.Holman, 1992)

$$\Delta H = \langle Cp^{ig} \rangle_H (T_2 - T_1) + H_2^R - H_2^R = 0$$

If natural gas as ideal at final condition,

$$H_2^R = 0$$

Equation above become,

$$\mathbf{T_2 - H_2^R / \langle Cp^{ig} \rangle_H + T}$$

With initial condition,

$T_1 = 301.15$ K

$P_1 = 3000$ psig $= 106.84$ bar (1 bar $= 14.5038$ psia)

So;

$T_{r1} = 301.15 / 198.64 = 1.5161$

$P_{r1} = 206.84 / 46.23 = 4.472$

$B^O = 0.083 - 0.422 / T_r^{1.6}$

$B^1 = 0.139 - 0.172 / T_r^{4.2}$

$dB^0 / dT_r = 0.675 / T_r^{2.6}$

$dB^0 / dT_r = 0.722 / T_r^{5.2}$

as $T_{r1} = 1.5161$, $P_{r1} = 4.472$, (J.P.Holman, 1992)

$B^O = -0.1338$

$B^1 = 0.1090$

$dB^0 / dT_r = 0.2288$

$dB^1 / dT_r = 0.0829$

For H^R equation:

$$H^R/RTc = Pr\ [B^O - TrdB^0 / dT_r = \omega\ (B^1 - TrdB^1 / dT_r)]$$

$$H^R/RTc = 4.472\ [-0.1338 - 1.5161\ (0.02288) + 0.02\ (0.1091 - 1.5161\ \{0.0829\})]$$

$$H^R = 4.472\ (-0.4810)(8.314)(198.64)\ 3$$

$$H^R = 3554.16\ J/mol$$

For above parameters,

$$Cp^{ig} / R = 1.7305 + 9.6608 \times 10^{-3}T - 20184 \times 10^{-6}T^2$$

For initial calculation, assume $<Cp^{ig}>$ near to initial 301.15 K.

$$<Cp^{ig}>_H = 36.9290\ Jmol^{-1}K^{-1}$$

so,

$$\mathbf{T_2 = H1R / <Cp^{ig}>_H + T_1}$$

$$T_2 = -3554.16/36.9290 - 301.15 = 204.9069K$$

Take the average temperature to get $<Cp^{ig}>_H$,

$$Tam = (204.9069 + 301.15) / 2 = 253.0285K$$

$$<Cp^{ig}>_H = 33.5481\ J\ mol^{-1}K^{-1}$$

$$T_2 = 195.20K$$

Third iteration,

$$Tam = 200.0573K$$

$$<Cp^{ig}>_H = 29.7292\ J\ mol^{-1}K^{-1}$$

$$T_2 = 181.60K$$

Fourth iteration,

$$Tam = 188.40K$$

$$<Cp^{ig}>_H = 28.8751\ J\ mol^{-1}K^{-1}$$

$$T_2 = 178.06K$$

Fifth iteration,

$$Tam = 179.83K$$

$$<Cp^{ig}>_H = 28.2441 \text{ J mol}^{-1}K^{-1}$$

$$T_2 = 175.31K$$

Six iteration,

$$Tam = 176.69K$$

$$<Cp^{ig}>_H = 28.0120 \text{ J mol}^{-1}K^{-1}$$

$$T_2 = 174.27K$$

Seven iteration,

$$Tam = 174.79 K$$

$$<Cp^{ig}>_H = 27.8717 \text{ J mol}^{-1}K^{-1}$$

$$T_2 = 173.63K$$

$$Tam = 173.95 K = 174.00 K = -99.25^{o}C$$

From the calculation, the temperature of the gas will decrease to –99.25 °C, so the regulator temperature range must have minimum temperature –99.25 °C. However, the heat from te surrounding and constant decreasing inlet will give the change of temperature drop. A experiment has been carried out for regulator test on the temperature drop cause by te pressure change from 3000 psig to 70 psig in normal condition, 28 °C. The maximum temperature drops to 13.7 °C. (Constan 1997)

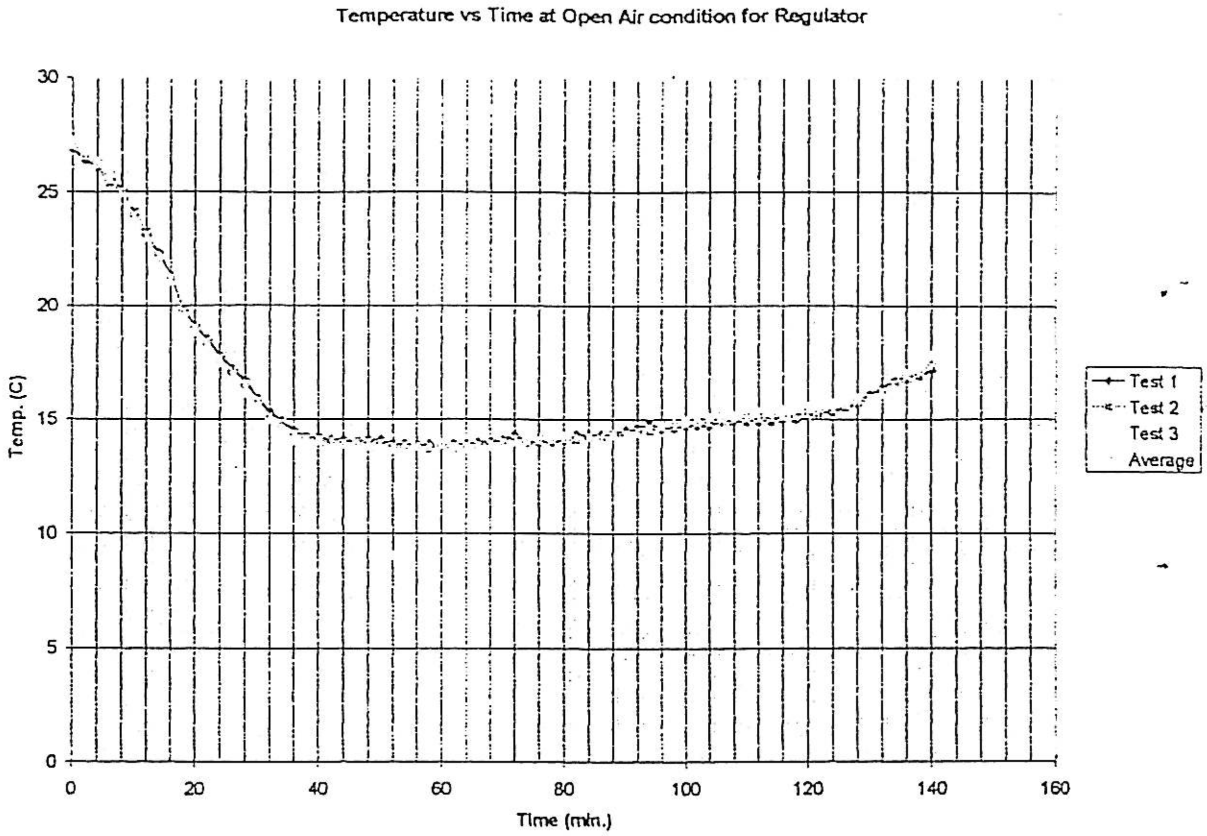

Figure 5.5 : Temperature Trend for Regulator at open air system.

Model 13.1 Fisher regulator as been selected as first stage regulator to regulate gas pressure from 3000 psig to 70 psig. The specification of regulator is listed at table 5.1. Second stage regulator was to regulate the gas pressure from 70 psig to 5 psig as the gas needed at the mixer. This regulator was modifying from liquefied petroleum gas regulator, which as maximum inlet pressure of 250 psig and outlet pressure of 15 psig.

Table 5.1: Regulator Specification

Type	13.1F
Maximum Inlet Pressure	6000 psig
Maximum Emergency Outlet Pressure	250 psig
End Connections	¼ inc NPT female
Body and Bottom Cap and Spring	-
Case	Forged Brass
Orifice	303 Stainless Steel
Regulator Spring	Zinc-plated steel
Diaphragm plate	Zinc-plated steel
Adjusting Screw	Plated Steel
Upper Spring Seat	Plated Steel
Diaphragm	302 stainless steel
Operation Temperature	-29 to 82^{O}C

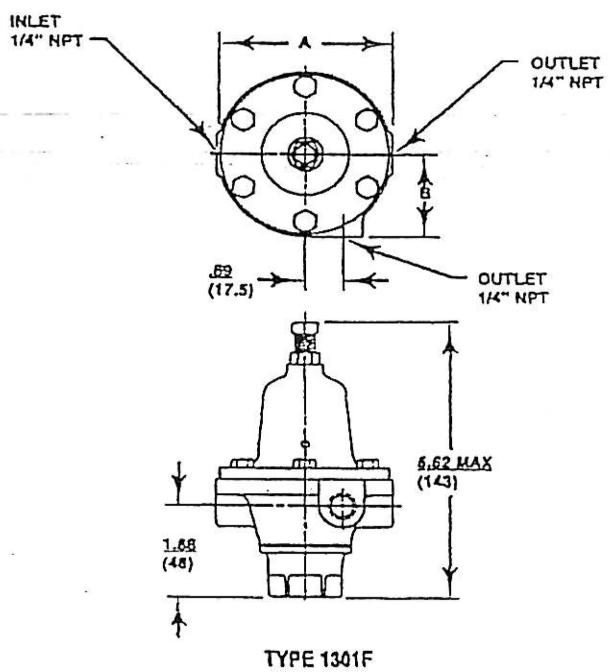

Figure 5.6 : Regulator Dimension

5.1.2 Test Equipment

A set of equipment has been used to measure the power output of motorcycle and exhaust emission.

5.1.2.1 Engine Dynamometer

An engine dynamometer has bee set-up at Gas System Laboratory Universiti Teknologi Malaysia using an alternator with ten 100W bulbs plus seven 1kW spotlight. The diagram below shows the setting of the dynamometer.

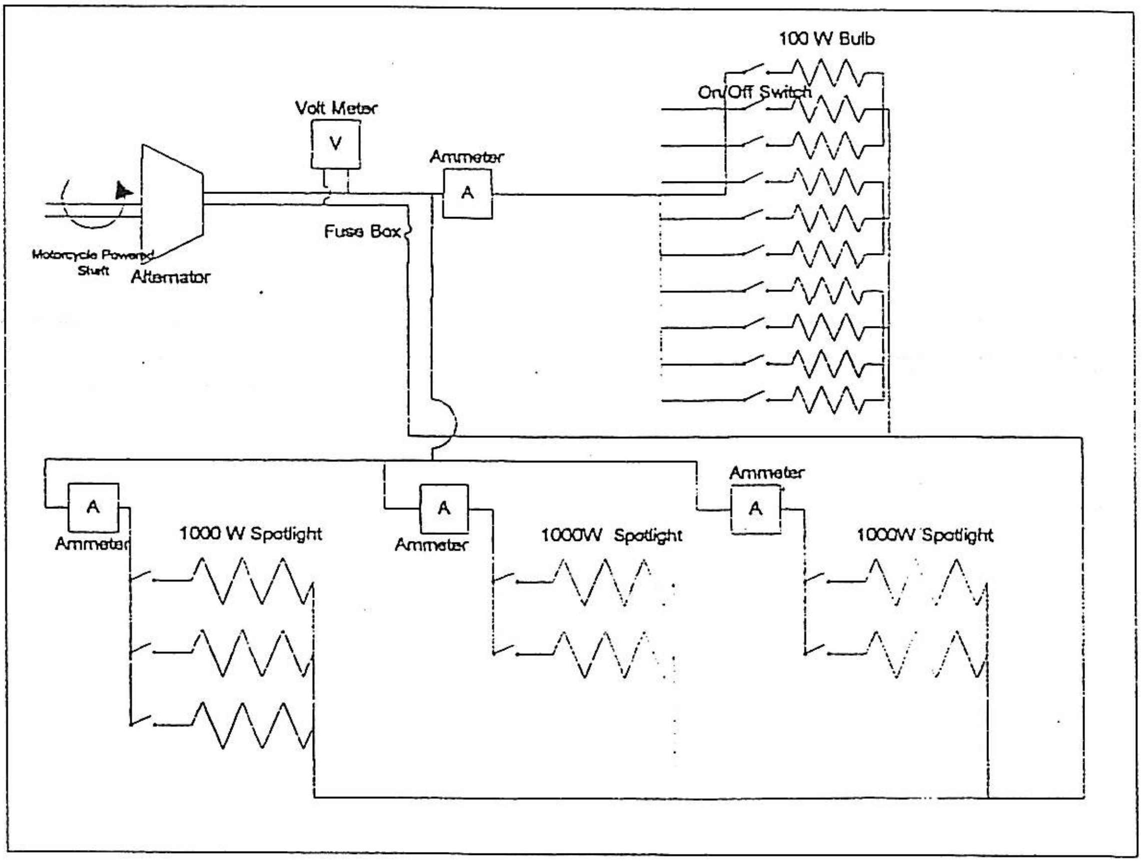

Figure 5.7 ; Engine dynamometer system

a. Alternator

An alternator has been installed at the test rig, which can give a maximum output of 7kW@ 1500rpm. Below are the data of the alternator specifications;

Table 5.2: Specification of alternator

Type	ST-7.5
Output (kW)	7.5
Number of Phase	1
Voltage (V)	230
Current (A)	32.6
Power Factor	1
Speed (rpm)	1500
Frequency (Hertz)	50
Weight (kg)	119

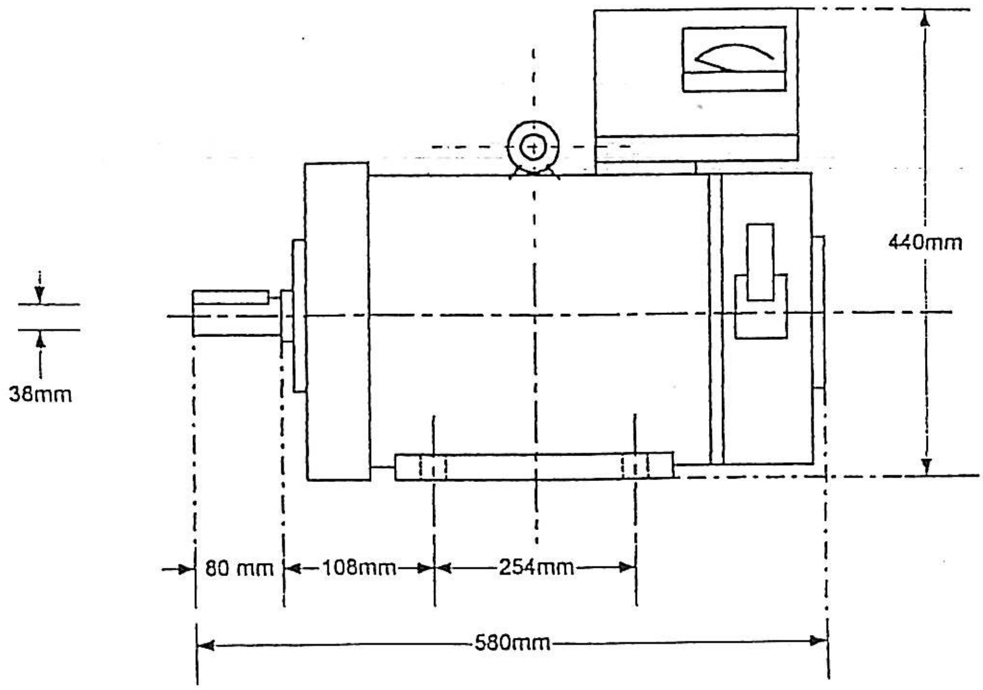

Figure 5.8: Alternator Dimensions

b. Load Control System

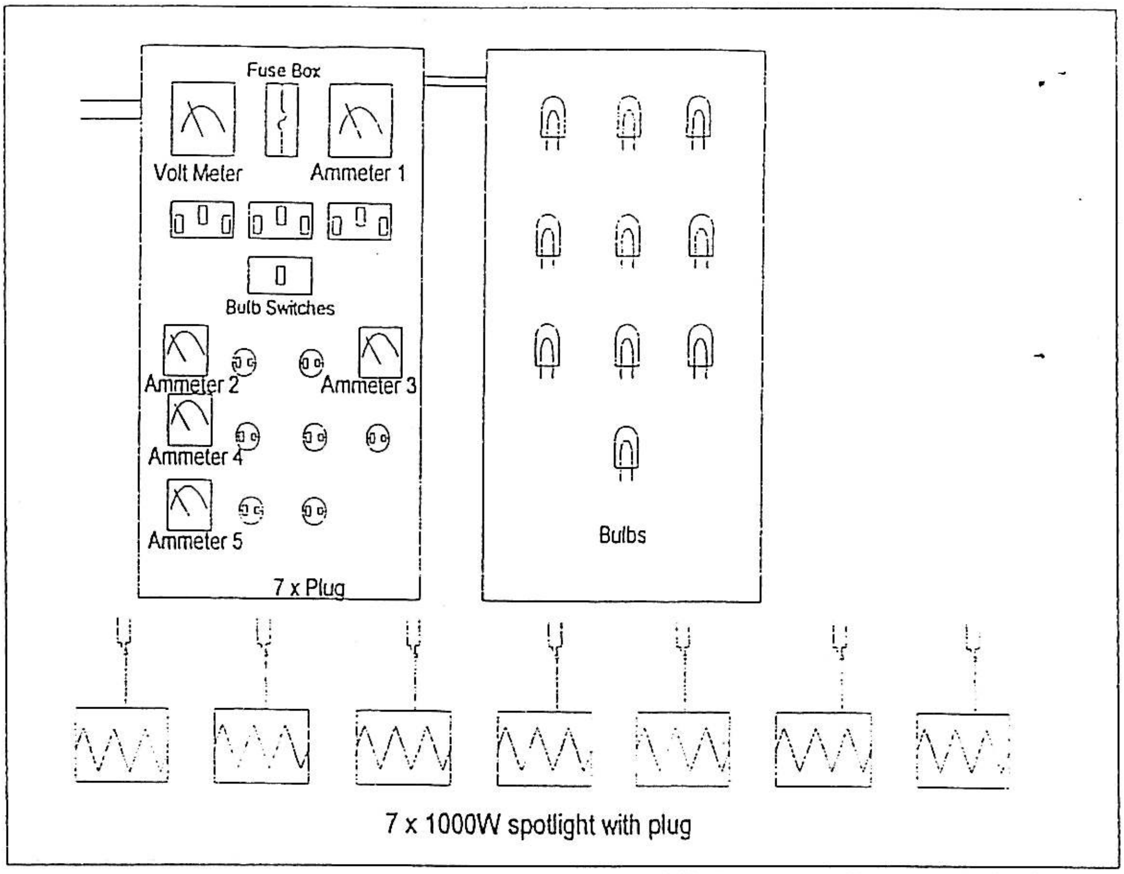

Figure 5.9: Load Control System

c. Bulbs and Spotlights

Ten bulbs and seven spotlights had been installed to provide load to the alternator for performance test, which is simulated to road condition. The bulbs were 100-watt (W) and 1000 kilowatt (1kW) for the spotlights.

d. Ammeter (1,2,3,4&5) and voltmeter

To measure the load of spotlights and bulbs or power output of the engine, the voltage and ampere of the current were taken. For ampere, five ammeters have been installed. Ammeter number 1 is to measure the ampere of 100 watt bulb, ammeter number 2 is for the first 1000 watt spotlight and ammeter number 3 is for the second spotlight. However, ammeter number 4 is for three spotlights and the others use ammeter number 5. Voltmeter is for the measuring of the system voltages. For accurate measurement, all meters had been calibrated using Cole-Parmer digital multimeter, model 26830-30. Below is the specification of multimeter.

Table 5.3: Specification of multimeter

Type		E-26830-30
DC Voltage	Range	400mV,4V,40V,400V,1000V
	Accuracy	± (0.5% of reading + 1 digit)
AC Voltage	Range	400mV,4V,40V,400V,750V
	Accuracy	≤ 400V : ± (1.2% of reading + 3 digits) 750V : ± (1.5% of reading + 3 digits)
DC Current Range		400μA, 4mA, 40mA, 400mA, 20A.
AC Current Range		400μA, 4mA, 40mA, 400mA, 20A.
Resistance Rannge		400Ω, 4kΩ, 40kΩ, 400kΩ, 4MΩ, 40MΩ, 400MΩ

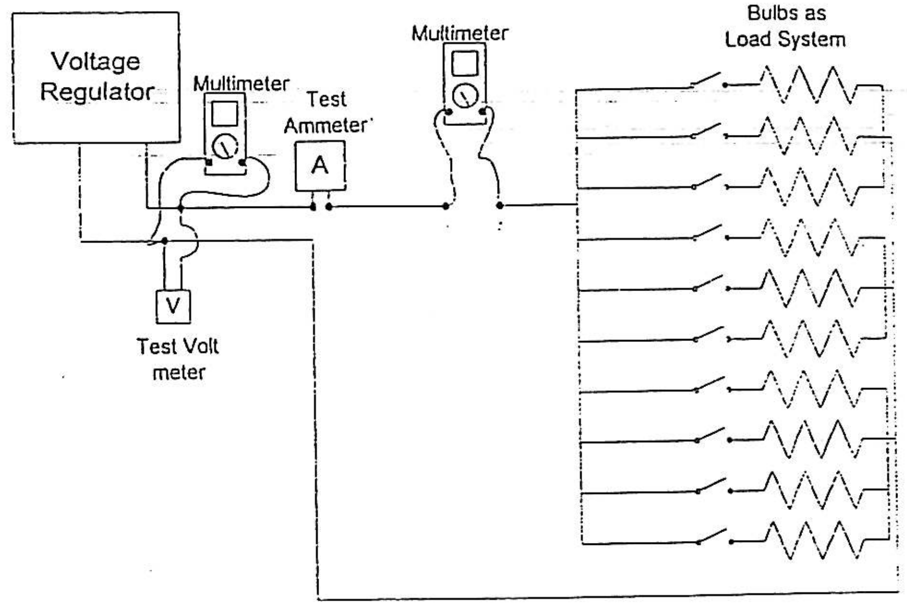

Figure 5.10 : Voltmeter and Ammeter Calibration system

To calibrate the ammeter and voltmeter, a system as above has been set-up. A set of bulbs has been fitted as load system to create different amperes to test the ammeter. The calibration procedure are as below:

a. Switch on the multimeters.
b. Switch on the voltage regulator and adjust it to 100 V.
c. Take the voltmeter reading ad multimeter reading for the output voltage.
d. Adjust the voltage to 240 V.
e. Switch on the bulb one by one and take the ammeter ad multimeter reading each time we increase the ampere.
f. Repeat step (d) until (e) for ammeter number 2,3,4&5.

The calibration data can be found at appendix A. all the ammeter accuracy is within the standard.

Table 5.4: Ammeter Calibration Data

Ammeter	Error % Range	Average Error % (Full Scale)
1	0.0 to 3.3	0.93
2	0.0 to 2.2	0.25
3	-2.86 to 0.0	-0.95
4	-2.18 to 0.0	-.55
5	-1.96 to 2.04	0.45

e. RPM Meter

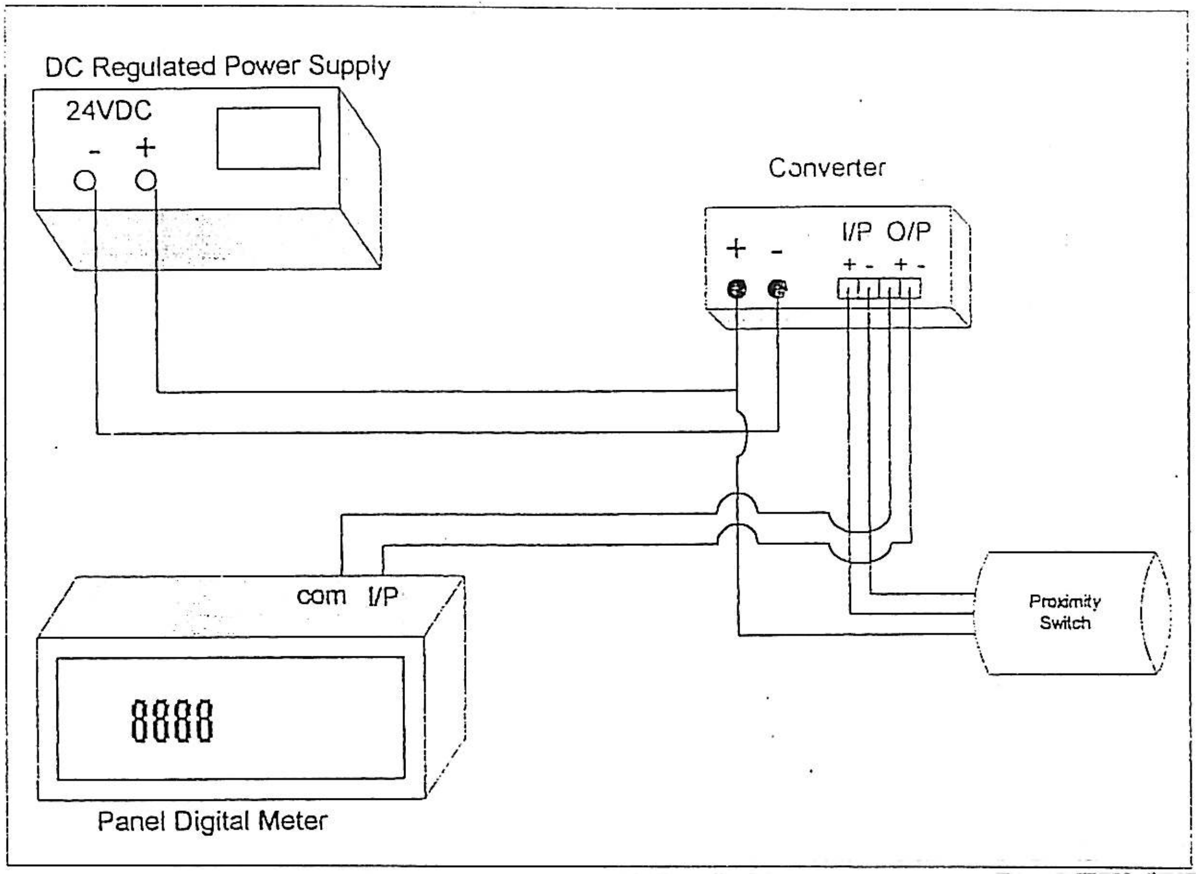

Figure 5.11: RPM Meter System

A RPM meter system has bee installed to determine the revolution of shaft turning. A proximity switch has been fixed near the shaft to scan the turn of the shaft. The signal will be send to converter and send to digital Panel Meter, Model P-596-DP8A0, for display. Specification of proximity switch model E2E-X5E1 is as shown below:

Table 5.5: Specification of RPM Sensor

Type	E2E-X5E1
Detection Distance	5mm ± 10%
Setting Distance	4.0 mm
Differential Travel	≤ 10%
Response Frequency	0.6 kHz
Supply Voltage	24 VDC
Current Consumption	≤ 13 mA
Control output	≤ 200 mA
Operating Temperature	-40-85^{O}C

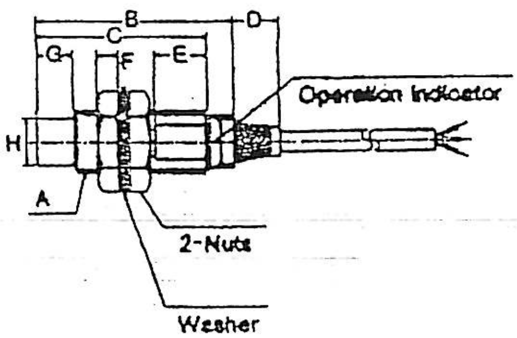

Figure 5.12: RPM sensor Dimensions

Calibration of RPM meter has been done at Mechanical Aerodynamic Laboratory. The Faculty of Mechanical, Universiti Teknologi Malaysia. A compressor motor rotation has been measured by using a laser tachometer and compared with the revolution per minute used in this project.

f. Temperature Sensor Meter

Thermocouples are the favorite sensors for measuring all kinds of temperatures. They provide high accuracy, rapid response ad easy application over wide temperature ranges. Two thermocouples, Barnant 115, model 600-2180 had been used in this project. Below is the thermocouple diagram

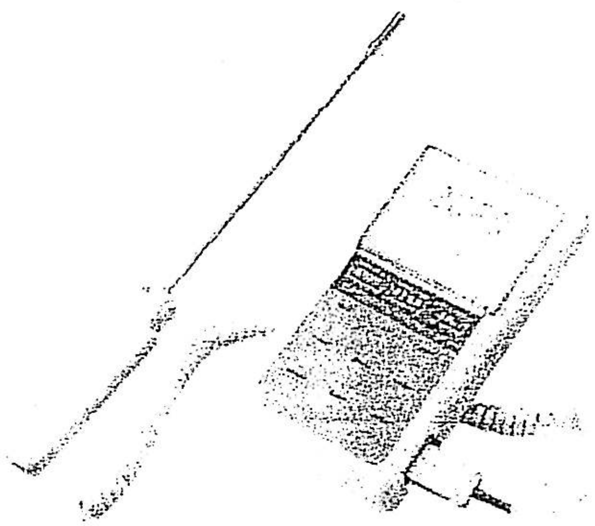

Figure 5.13: Thermocouple

All thermocouples used I this project had been calibrated, following the operating manual procedure. Two reference points are the freezing point and the boiling point for water.

Field calibration:

The New CAL functio allows single-point calibration of the probe, either manually or automatically. The J.T.E.K has a memory retention capability to hold a separate calibration value for each of the four-thermocouple types, even while the power is off.

1. Manual Calibration

- Place probe at reference temperature point
- Press the CAL key. Note that the CAL indicator will blink.
- Hold down either the INC (Increment) or DEC (Decrement) key until the desired calibration temperature is displayed. For example, if the current reading is higher than the reference temperature, press the DEC key until the display reads the actual calibration reference temperature.
- Press the ENTER key to store this calibration off set value
- The CAL indicator will stop blinking, but will remain in the display to verify that the displayed readings now include a field calibration offset.
- To erase the calibration offset, press the sequences the CAL and CLEAR key.

2. Automatic Calibration

In the automatic calibration mode, the instruments self calibrates to the freezing or boiling points water.

- Freezing : $0^{O}C$ or $32^{O}F$
- Boiling : $100^{O}C$ or $212^{O}F$

Here is the procedure:

- Place the probe in boiling or ice water and let it stabilise.
- Press in sequences the VAL and ENTER keys. The unit will automatically detect at which point (freezing or boiling) it is near and calibrated to that point.
- The CAL indicator remains to verify that this and all subsequent displayed readings include a field calibration offset.

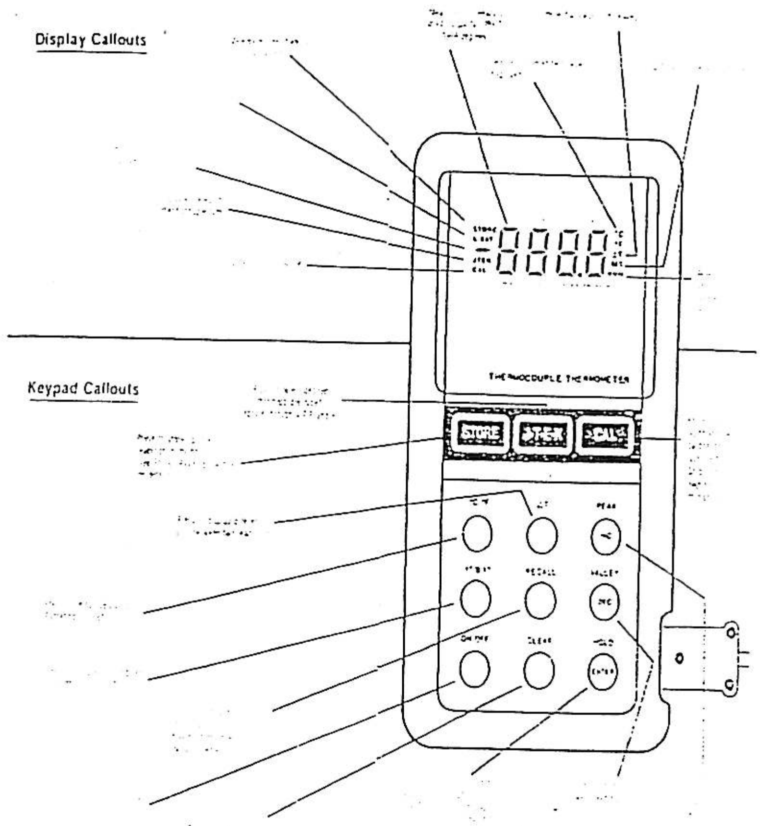

Figure 5.13: Thermocouple Instruction

Specification of Thermocouple:

- Operational Ranges

  The J.T.E.K instrument has a high number of calibration points over extended ANSI ranges for thermocouples. This permit meter calibration accuracy to better than 0.4^{O}C over full range, with no discontinuities of jumps from one reading to the next. Noiseless reading are provided via microprocessor signal averaging and front-end analogue signal filters.

- Range /Accuracy

Thermocouple-Type	Temperature Range		Accuracy
	^{O}C	^{O}F	
J	-190 to 1000	-310 to 1832	
K	-250 to 1375	-418 to 2507	0.1% Reading
E	-250 to 1000	-418 to 1832	$\pm$ 0.4%
T	-250 to 400	-418 to 752	

g. Hygro-Thermometer

Pacer's Models DH301 are designed to check relative humidity and temperature I the air conditioning servicing, computer rooms, storage, heating, environmental industries, plant maintenance and research and development facilities. Its application is not limited, however, to these uses. The units feature the LCD display with a thin film capacitance type sensor for measuring % RH and platinum resistance sensor for measuring temperature. In this study, DH301 is used as the apparatus for relative humidity and has been calibrated by Translab with ±1.5% accuracy.

Table 5.6: Specification of Hygro-Thermometer

Probe	Capacitive (Thin File)
Range	5.0% to 95.0% RH
Resolution	0.1%
Accuracy	± 2%
Display	5" LCD display, 3 ½ digits
Response Time	Humidity :90% of measuring value in 15 seconds
Temperature Drift	± 0.5% per 10^{O}C
Operating Temperature	Instrument : 32^{O}Cto 120^{O}F, Probe : -50^{O}C to $+175\ ^{O}$F

h. Phase I : Test Rig Plan

Phase I test rig has been set up at Gas System Laboratory for flow rate control test, performance test and lubricating oil test. However because of the limitation at the alternator where the maximum revolution per minutes is limited to 1500 rpm so for high engine speed this test rig is not suitable. For exhaust emission test and performance test at high speed, the conversion kit had been sent to MODENAS where chassis dynamometer was used.

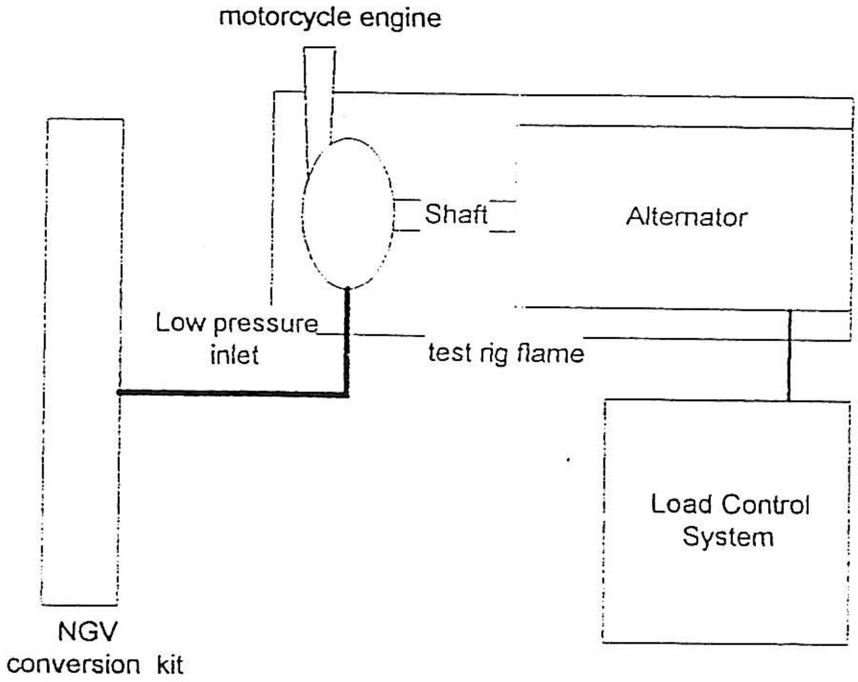

Figure 5.14: Plan of Phase I Test Rig

5.1.2.2 Chassis Dynamometer System

CycleDyn Pro SF-250, chassis dynamometer has been used for exhaust emission and performance test. This dynamometer will be suitable for running emission test to all current legislative requirements and will meet the performance and calibration requirements of SAE (Society of Automotive Engineers). ECE (European Community), JIS (Japanese Institute for Standardization), (DIN (Deutsche Industries Norm) test procedures. This dynamometer has a roll with equivalent vehicle weight of 450 lbs. (205kg). This equivalent vehicle weight procedures accurate test results for the widest possible range of motorcycle.

This dynamometer includes an Eddy Current Absorber model with the equivalent vehicle weight of the roll, 280 lbs. (127 kg). The Eddy Current absorber itself adds 65 lbs. (30kg) for total mechanical inertia of 245 lbs. (157kg). With this Eddy Current absorber, it is possible to add any amount of additional electrical inertia simulation to simulate a rate of acceleration for any heavier vehicle within the design parameter of the system.

On an inertia- only dynamometer, power measurement is only under wide open throttle condition. For the power measurement at constant speed, partial throttle or during throttle transition will be difficult to measure by using only a dynamometer.

The CycleDyn Eddy Current absorber, which was used at this project in MODENAS, allows simulation of any operation conditions, CycleDyn Dynamometer With Eddy Current absorber can perform a variety of automated tests.

In this study the motorcycle used was KRISS 110, MODENAS. A configuration setting file should be filled for chassis dynamometer to stimulate this type of motorcycle runs on to it. Required data are listed at table 5.7. The CycleDyn using WinDyn to control the automatic tests and records. Below is a sample display of WinDyn.

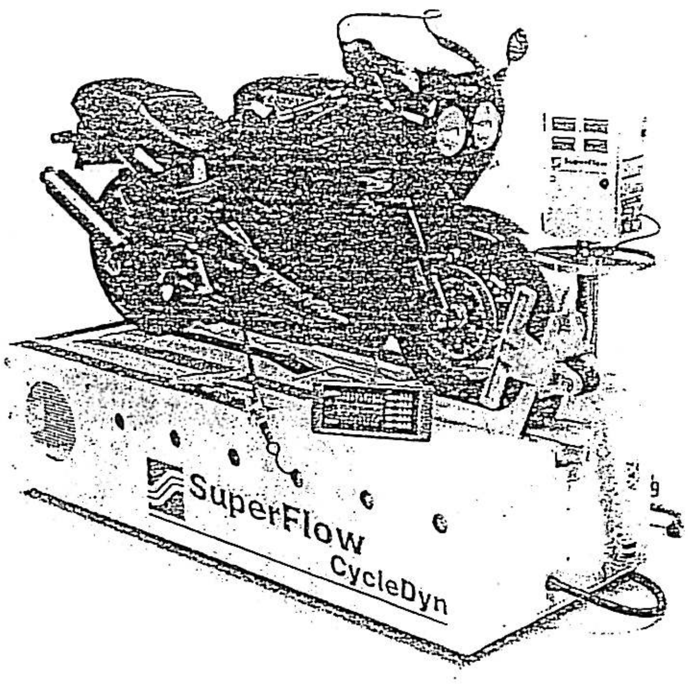

Figure 5.15: Chassis Dynamometer

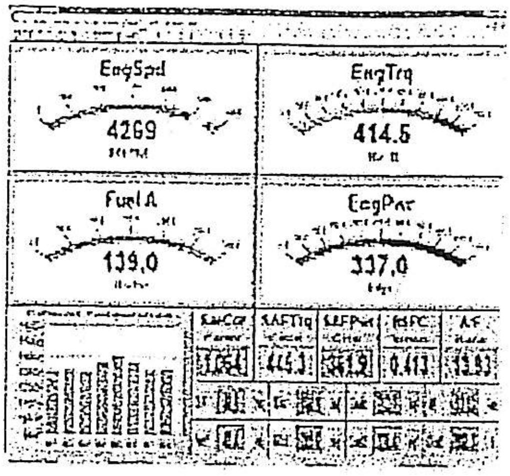

Figure 5.16 : WinDyn Display

Table 5.7 : Specification of Chassis Dynamometer

Engine Bore (EngBor)	53.00 mm
Engine Stroke (EngStr)	50.60 mm
Engine Cylinder (EngCyc)	1 Number
Engine Cycle (EngCyc)	4 Cycle
Spark Pulse (SparkP)	1.0 Pul/Rv
Induction System (Induct)	0 Type (Naturally Aspirated)
Fuel Specific Gravity (FuelSG)	0.6 (natural gas Coefficient
Estimated Effective Frontal area of the test vehicles times the drag coefficient (FaxCd)	0.4 m^2
Counts Per Revolution (Cts/Rv)	1
Tire Diameter (TirDir)	58.4 cm
Tire Loss Coefficient (TirLos)	0.012 (MODENAS) Ratio
Drive Efficiency (DrvEff)	0.880 (MODENAS) Ratio
Rear axle drive weight (RrAxWt)	120 kg
Total Weight (TotWt)	160 kg
Engine Ratio (EngRat)	3.048 Ratio
Motorcycle Rotating Inertia (MCrInr)	11 (default) kg

CHAPTER VI

CONCLUSION AND RECOMMENDATIONS

6.0 Conclusion

The research has successfully developed the conversion kit for conventional gasoline motorcycle. The MODENAS, KRISS 110cc engine can run using either gasoline or natural gas and produced a workable motorcycle. Early investigation indicated that the engine power while running with natural gas has reduced as compared to normal gasoline engine.

6.1 Recommendation

a) Using some computer simulation software to design the mixer, which take all parameters into account. Example of available software is '*Fluent*'.
b) Design a regulator which pressure output is compatible with the engine suction pressure at only condition of engine running.
c) Design a timing controller as the solution of natural gas flame speed problem.
d) Study the natural gas engine performance
e) Study the emission characteristic the engine

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