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JUDUL: **DESIGN OF A COMPRESSED NATURAL GAS (CNG) MIXER FOR 1500CC ENGINE**

SESI PENGAJIAN: 2007/2008

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

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DESIGN OF A COMPRESSED NATURAL GAS (CNG) MIXER FOR 1500CC ENGINE

AUDI B SYA RIZAL

A report submitted in partial fulfillment of the
requirements for the degree of
Bachelor of Mechanical Engineering with Manufacturing

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

NOVEMBER 2007

STUDENT DECLARATION

I declare that this thesis entitled "*Design of a compressed natural gas (CNG) mixer for 1500cc engine* "is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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Date : 23 NOVEMBER 2007

DEDICATION

Dedicated to my beloved ones,
My father Mr Sya Rizal Abdullah
My mother Mrs Mariam Tahir Abu Halim
My brothers Mr Adi Russman Sya Rizal and Mr Johan Sya Rizal
My sister Ms Ena Sabreena Sya Rizal

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ABSTRACT

Natural gas vehicle (NGV) is a new discovery technology in Malaysia. Some advantages of the characteristic of natural gas compared to conventional fuel make it become the most important alternative fuel. The mixer is an important device in a compressed natural gas (CNG) kit to provide a proper air-fuel mixture for engine to run in the optimum condition. In this report, the literature of natural gas is presented and the characteristics of air and gas flow in the mixer is simulated using COSMOS software in order to have a better understanding of how mixture of air and fuel through the CNG mixer. A test on a 1500cc engine also been done to evaluate the designed mixer performance.

ABSTRAK

Teknologi Automotif menggunakan gas asli sebagai bahan api merupakan satu bidang yang baru dipelopori. Pelbagai kelebihan yang terdapat pada ciri-ciri gas asli berbanding dengan bahan api yang lain menjadikannya salah satu bahan api alternatif yang sangat penting pada masa kini. Mixer merupakan satu alat yang penting dalam sistem kenderaan yang menggunakan gas asli mampatan terutamanya untuk menyediakan campuran udara dengan gas yang sempurna kepada enjin supaya enjin dapat berfungsi dengan baik. Dalam laporan ini, kajian ilmiah mengenai gas asli telah dibentangkan dan sifat-sifat aliran udara dan gas asli dalam mixer disimulasi dalam perisian COSMOS untuk memahami dengan lebih mendalam lagi bagaimana udara dan gas mengalir melalui mixer. Satu kajian terhadap sebuah enjin 1500cc dilakukan untuk menguji prestasi mixer baru yang direkabentuk itu.

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LIST OF SYMBOLS

Qa	-	Engine flow rate
A	-	Cross section area
A/F	-	Air/Fuel
N	-	Engine speed
η_v	-	Volumetric efficiency
V	-	Engine displacement
ma	-	Air mass flow rate
mf	-	Fuel mass flow rate
P	-	Pressure
CO_2	-	Carbon Dioxide
T	-	Temperature
R	-	Gas constant
ρ	-	Density
V	-	Velocity
g	=	Gravity
rc	-	Compression ratio
rpm	-	Revolution per minute

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CHAPTER 1

INTRODUCTION

Natural gas vehicle (NGV) is a new discovery technology in Malaysia. Some advantages of the characteristic of natural gas compared to conventional fuel make it become a most important alternative fuel. The mixer is an important device in a compressed natural gas (CNG) kit to provide a proper air-fuel mixture for engine to run in the optimum condition. Compressed natural gas (CNG) also called as a natural gas vehicle (NGV) is an alternative fuel that is suitable for automotive use. It is actually the product of the underground decay of organic residuals (animal, plant, etc) that have changed their molecular structure over thousands of years. Then chemical process take place compressed over the organic residuals at high pressure (200bar, approximately 3000psi) and become one of the alternatives to replace the petrol as a fuel. Compressed natural gas contains 92.29 of methane and the rest are other gas such as buthane, propane and other trace gases. Therefore compressed natural gas formally known as methane. Actually there are many advantages of the compressed natural gas compared to the petrol. The advantages are the life of an engine actually increases economical, low emission, better drivability and other advantages. In this project, a proper design of the CNG mixer must be construct according to a proper calculation of the air flow.

1.1 Objectives

The performance of compressed natural gas engine in term of power output, brake torque, and volumetric efficiency is very sensitive to the air/fuel mixer design. A litter lack in the mixer design will cause a number of performance drop in the CNG engine. Therefore, a proper design of mixer is very importance in a CNG conversion system. The objective of this work is to design a most suitable CNG mixer for a 1500cc engine air requirement.

1.2 Scope

The scope of this work is:

1. Design a CNG fuel/air mixer, which suitable for a 1500cc four cylinder in-line engine with mechanical conversion system. More concern will be put on the CNG inlet of the mixer and the flow in the mixer.
2. Construct a designed mixer and run an analysis by using COSMOS Flow Works

1.3 Problem Statement

Although there is several of benefits of natural gas fuel, however, current natural gas engine are simply the conversion either the petrol or diesel that are far away from the optimum design. It causes a drop in engine power outputs and efficiency. Generally the conversion of gasoline engine to natural gas will cause a power loss of 10 to 30 percent. The air/fuel mixer restriction to the air flow causes a large part of the losses. About 10 to 20 percent of the 30 percent losses are associated to the obstruction of air flow by the mixer itself.

Although there is various types of mixer in the market percent time, but for every single engine the requirement to the mixer is differences. Therefore, for an engine to achieve the optimum performance when running with CNG, a deeper study on the air/fuel mixer device should be carried out

1.4 Previous Study

According to the previous study on design the CNG mixer, still the result not achieve the optimum performance on the engine which means the mixing of air and fuel still cannot give the engine a better performance while the engine running on CNG as a fuel

1.5 Expected Outcome

In this final year project, the expected outcome is to design a CNG mixer with proper parameters to achieve optimum performance and better air/fuel ratio

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, discussed about the literature study related to the project. Including the definition and details about the compressed natural gas such as the background of the compressed natural gas, the advantages by using the CNG in vehicle, the contents of the compressed natural gas and how that compressed natural gas exist and the process, the conversion system of the CNG vehicle and also the component for the conversion system from petrol to CNG. In this chapter also discussed about the application in the CNG mixer how it works and how the air flow through the mixer.

2.2 Alternative Fuel

Convention fuels have remained almost unchallenged since the motor vehicle was invented. However, their source is finite. Recent estimates of the remaining petroleum resources in the world both in known field and those to be discovered should last between 40 and 70 years at current rates of usage. Our own country, Malaysia has about 4.3 billion barrels of crude oil that will last for only 19 years. At the same time, there will likely increase the number of automobiles and other internal combustion (IC) engines. Although fuel economy of engine is greatly improved from the past and will probably continue to be improved, numbers alone dictate that there will be a great demand for fuel in the future years. Gasoline will become scarce and costly. So, it is important for us to be prepared for a future with alternative fuel.

Another reason motivating the development of the alternative fuel for IC engine is concern over the emission problem of gasoline engine. Compare with other air-polluting system, the large number of automobiles is a major contributor to the air quality problem of the world. Vast improvements have been made in reducing emissions given off by an automobile engine. Additional improvement such as using alternative fuel is needed due to the increasing number of automobiles. Emissions from electricity, natural gas can be as much as 90 percent lower in toxins than emissions from vehicle fueled with gasoline.

However, very few alternative fuels have been used commercially. The main problem is most alternative fuels system is very costly at present. The cost of manufacturing, distribution, and marketing all would be less. Another problem with alternative fuels is the lack of distribution points (fueling station) where the fuel is available to the public. The public will be reluctant to purchase an automobile unless there is a large-scale network for fueling station. On the other hand, it is difficult to justify building the network for these service stations until there are enough vehicles to make them profitable. Anyway some cities in developed countries are starting to make available a few distribution points for these fuels, like propane, natural gas and methanol. At the same time, some third world countries have been using manufactured alcohol fuel as their main vehicle fuel due to the high cost of petroleum product.

2.3 Natural Gas

Natural gas is one of the most abundant fuels in nature. Although we do not have an absolute estimate about planetary reserves, we can safely assume that natural gas is more abundant than oil and as an automotive fuel, is second only to hydrogen. Natural gas is the product of the underground decay of organic residuals (animal, plant, etc) that have changed their molecular structure over thousands of years. This is the most common explanation for the formation of natural gas, also called "Organic Theory ". During countless millions of years, dead plants and animal sunk at the bottom of lakes and oceans. These remains were covered by mud, sand and other debris. The accumulation of such materials exerted high pressures on the buried materials with the passing of the millennia. Such pressures in turn created high temperatures. Chemical action took place and converted these remains into natural gas and crude oil.

In its pure state, natural gas is odorless, colorless, and tasteless. Natural gas is a mixture of components, consisting mainly of methane (about 92 percent). The other 8 percent is made up of various gases along with small amounts of water vapor. These other gases include butane, propane, ethane and other trace gases. So, natural gas is always referred as methane. Table 1.1 shows typical composition of natural gas.

Table 2.1: Typical composition of natural gas

Component	Volume Percent	Mass Percent
Methane	92.29	84.37
Ethane	3.60	6.23
Butanes	0.29	0.99
Pentanes	0.13	0.53
Propane	0.08	2.06
Hexanes	0.08	0.39
Nitrogen	1.80	2.89
CO_2	1.00	2.52
Water	0.01	0.01
Total	100.00	100.00

2.4 Compressed Natural Gas as Fuel

Natural gas has been used as a stationary IC engine for many years. Recently, its potential use as vehicle fuel received much attention. Among the alternative fuel choices, natural gas seems to have a number of advantages. Substantial supplies of natural gas exist worldwide with much available in North America. At present, Malaysia has 2.3 trillion cubic meters (m^3) of natural gas reserves, which can last 80 years. Natural gas can be adopted in a wide range of automobiles (from light-duty passenger vehicles to heavy- duty utility vehicle). The use of natural gas of transportation fuel will also lessen the dependence on petroleum products.

Because of its clean burning nature and the fact that it is not made from petroleum as gasoline and diesel are, many automakers around the world are developing vehicles to run on natural gas. Cars, vans, buses and small trucks generally use natural gas that has been compressed, called compressed natural gas (CNG) and stored in high pressure cylinders. A compressed natural gas vehicle stores gaseous fuel at pressure of 165.5bar (2400psi) to 248.3bar (3600psi). Even at a pressure of 248bar (3600psi), a unit volume of CNG has less than one-fourth of the energy content of gasoline, which means a much greater storage requirement for the vehicle.

Table 2.2: Energy content of alternative fuels relative to petrol and diesel (Maxwell, 1995)

Fuel	Density (kg/m3)	Energy Content (MJ/m3)	Energy Relative to equivalent mass of Petrol	Energy Relative to equivalent mass of Diesel
Petrol	621.8	4257	100%	91%
Diesel	622.2	4694	110%	100%
LPG	422.1	3113	115%	109%
Methanol	658.5	2100	49%	45%
Ethanol	652.5	2813	66%	60%
NG	351.2	2814	120%	113%

Table 2.3: Proven natural gas reserves, 1991, (Poulton, 1994)

Area	Trillion Cubic Meters	Billion Tones Oil Equivalent	Share of Total (%)
North America	7.5	6.7	6.1
Latin America	6.8	6.1	5.4
Western Europe	5.1	4.6	4.1
CIS/E Europe	50	45	40.4
Middle East	37.4	33.7	30.1
Africa	8.8	7.9	7.1
Asia/Australasia	8.4	7.6	6.8
Total	124.0	111.6	100.0

2.5 Advantages of Using CNG on the Engine

1. Economy:

   i) CNG is the most economical fuel and saves more than 55 % of your fuel expenditure over petrol.
   ii) It eliminates frequent vehicle maintenance.
   iii) Due to the absence of any lead content in CNG, the lead fouling of plugs is eliminated and plug life is greatly extended

Table 2.4: Different price between Petrol and CNG

	Petrol	CNG	Savings
Cost per liter.	RM 1.92	RM 0.81	-RM 1.11
Cost of 8 liters.	RM 15.36	RM 6.48	RM 8.88
Monthly Consumption.	RM 59.52	RM 25.1	RM 34.42
Yearly Consumption.	RM 700.8	RM 295.53	RM 405.27

2. Drivability:

CNG provide easy starting and smooth acceleration. While running on CNG, there is a power loss of approximately 5-15%, which can be minimized by using kits with a variable mixer and proper tuning (advancing the spark timing).

3 Environmental Friendly:

Environmental benefits provide an important argument for promoting natural gas in mobile applications. Since methane is the largest component of natural gas, we generally use the properties of methane when comparing the properties of natural gas to other fuels. Methane is a simple hydrocarbon, a substance consisting of carbon and hydrogen. There are many of these compounds, and each has its own number of carbon and hydrogen atoms joined together to form a particular hydrocarbon gas or fuel gas. Its simple, one carbon, molecular structure (CH_4) makes possible its nearly complete combustion. Its much simple and smaller molecules compare with gasoline (C_7H_{16})

2.6 Engine Conversion

Both gasoline and diesel engines can be easily converted to gas operation. Conversion from a gasoline engine to gas is very simple and straight forward. It is only require a gas fueling system. Very litter or no modifications are needed to the base engine.

For converting a diesel engine to gas, a spark system has to be use to replace the diesel fuel injection system since natural gas is not the type of auto-ignition fuel. Natural gas needs a mixture temperature of approximately 1000^0C to ensure the auto-ignition.

Natural gas conversion systems for vehicle consist basically of two types, mechanical (carbureted) and electronic (fuel injected). Mechanical systems have been used for many years and operate on the same principles as gasoline carburetor fuel metering system. The natural gas is mixed with the intake air in a fuel/air mixer. Electronic system utilizes injectors or flow control valve to meter the fuel into the intake air. In this work, the study will be done on the mechanical conversion system of a 1.5L four cylinders spark ignition engine.

2.7 CNG Conversion System

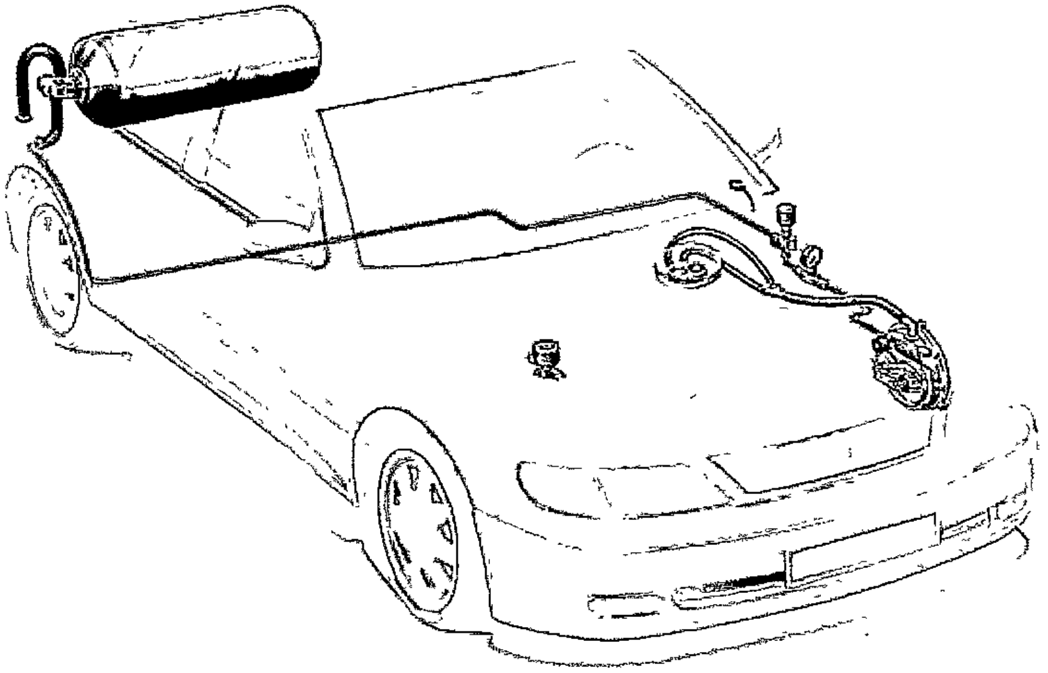


Figure 2.1: CNG conversion systems

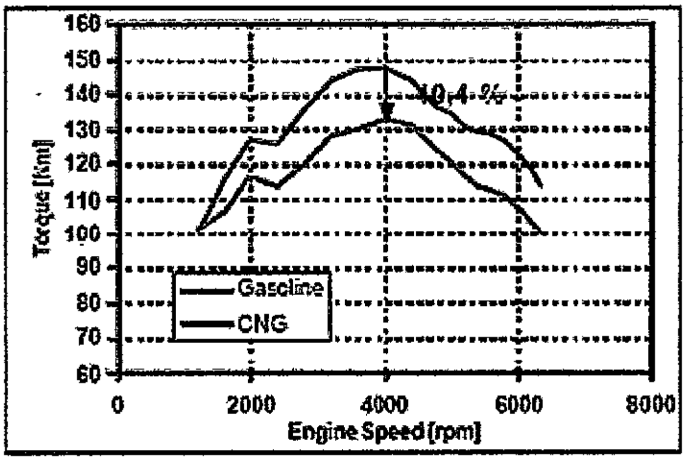


Figure 2.2: Torque of 1587cc Peugeot TU5JP4 with CNG conversion

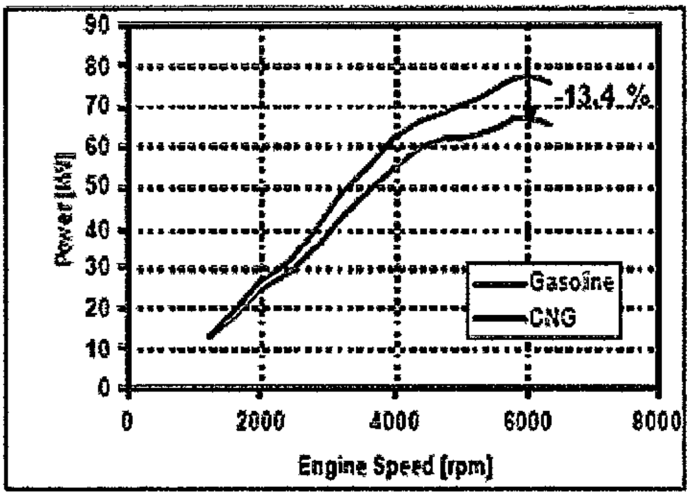


Figure 2.3: Power output of 1587cc Peugeot TU5JP4 with CNG conversion

Engine Performance

Power Output- Figure 2.3 shows the power characteristics of the test engine. The use of CNG led to 13.4% reduction in output and 10.4% torque reduction at WOT .For a petrol engine, power output tends to decrease around the stoichiometric A/F ratio because of thermal dissociation. To cope with the problem, thermal dissociation is avoided by setting the richer A/F ration. There was less thermal dissociation for CNG because the combustion temperature is low at around the stoichiometric A/F ratio. The torque difference between CNG and petrol engines is not conspicuous at low engine speed. They were almost the same up to 1500 rpm. This characteristic may result from the fact that CNG has a very high octane value, allowing ignition timing to be set at MBT(Minimum spark advance for best torque) at all engine speed.

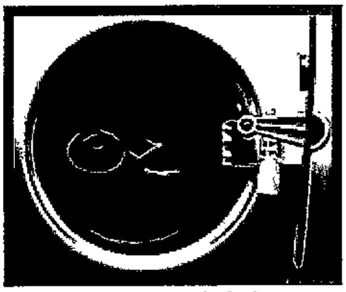
2.7.1 The Basic Component of a CNG Vehicle

1. Filler valve

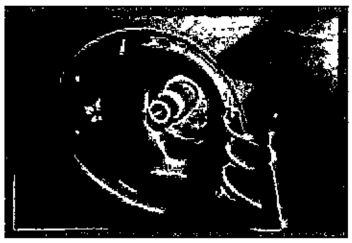
The valve is used to fill the vehicle's pressure tank with natural gas at CNG fuel stations. The filler valve can be located in the engine compartment (the usual solution for converted automobiles), near the gas tank inlet, or separately in a different place.

There are two filling methods - the "Italian" system (used chiefly in Italy) and the NGV 1 system (used in other European countries).

NGV 1 inlet:



near the gas tank inlet



in the engine compartment

in a separate location

Figure 2.4: Filler valve at CNG vehicle

2.Pressure tank + multi-valve

Most tanks for pressurized natural gas have a volume of 70-100 liters and are fitted with a multi-valve for safe and reliable operation. The multi-valve functions as an operating device, which closes the pressure tank when the ignition is turned off and controls the amount of gas flowing from the vessel, and as a safety mechanism, which automatically shuts off gas flow if the piping system is damaged (pressure falls) and releases gas from the vessel if the pressure exceeds a certain value or if a heat sensor detects a fire.

Pressure tanks are usually made of steel, but an increasing number of lightweight tanks made from aluminum or composite materials, as strong as steel but weighing up to three times less, have recently appeared on the market.While most converted cars have a CNG tank installed in the trunk, vehicles designed for the use of natural gas have a pressure tank below the chassis or in another suitable location.

Most buses have CNG bottles in the luggage compartment or on the roof (low-profile buses).

Automobiles - examples of locations of pressurized vessels:

in the trunk under the chassis

Figure 2.5: Example of locations of pressurized vessels

3. Connecting high-pressure pipe

During the filling process, the pipe brings natural gas from the filling valve to the pressurized vessel. Conversely, while the vehicle is in the natural gas mode, the pipe delivers gas from the bottle to the regulator.

4. Pressure gauge (optional)

The pressure gauge shows the pressure in the high-pressure section of the gas system (pressure tank, connecting pipe).

5. Gas pressure regulator

The regulator reduces the high pressure of gas to the desired level. It includes a closing valve. The regulator is located in the engine compartment, where it is connected to the internal cooling circuit from which it takes heat.

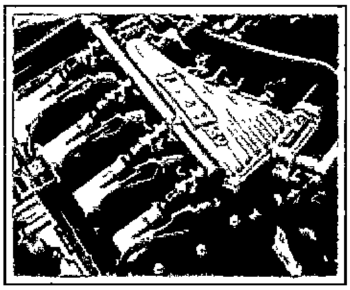
Vehicles with direct gas injection feature:

6. Electronic injectors

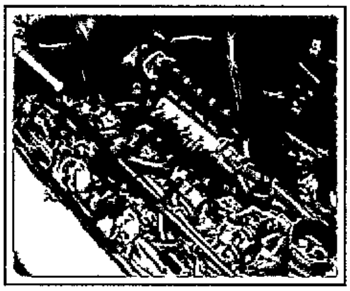
Injectors are devices that control the injection of gas into the intake manifolds of individual cylinders. They work sequentially, which means that natural gas is injected separately to each cylinder.

7. Injection rail

The injection rail is part of the injectors and brings natural gas from the pressure regulator to individual injectors.



CNG FIAT Multiple / injection rail



Skoda Fabia / injection rail

Figure 2.6: Type of injection rail

Vehicles with central gas mixing feature:

6. Stepper

Based on signals sent by the control unit, the stepper continually adjusts the quantity of gas entering the mixing system to ensure optimal power, fuel consumption, and emissions.

7. Mixer

The mixer mixes the fuel (natural gas) with air to create an explosive mixture. It has the same function as a carburetor or a fuel injection system in vehicles powered by gasoline.

8. Electronic control unit

The unit ensures correct operation of a vehicle powered by natural gas by working together with the gasoline control unit and supplying natural gas according to operating modes and signals sent from the engine.

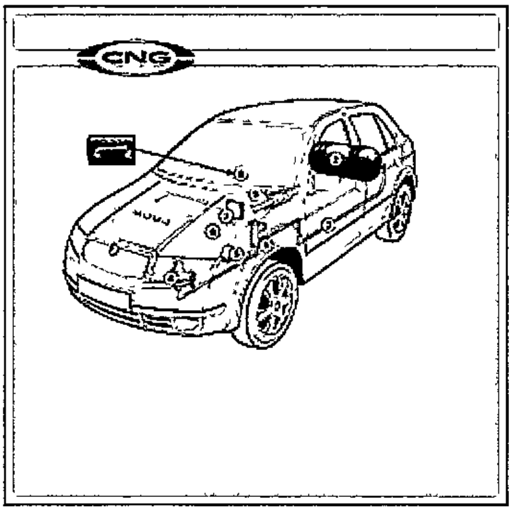
9. Natural gas/gasoline switch and fuel gauge

The switch and the fuel gauge are located on the dashboard in front of the driver; in mass produced CNG vehicles, they are incorporated into the dashboard. By switching from gasoline to natural gas, the supply of gasoline is stopped, and the gas intake from the regulator is opened. Gas regulation starts depending on information sent by the lambda sensor and the natural gas fuel gauge is activated.

10. Catalytic converter and lambda sensor

The lambda sensor analyzes the composition of exhaust fumes and sends information to the electronic control unit, which adjusts the supply of natural gas.

Diagram of an automobile powered by compressed natural gas



A) Skoda Fabia – direct fuel injection

Figure 2.7: Direct fuel injection

2.8 Examples Design of CNG Mixer

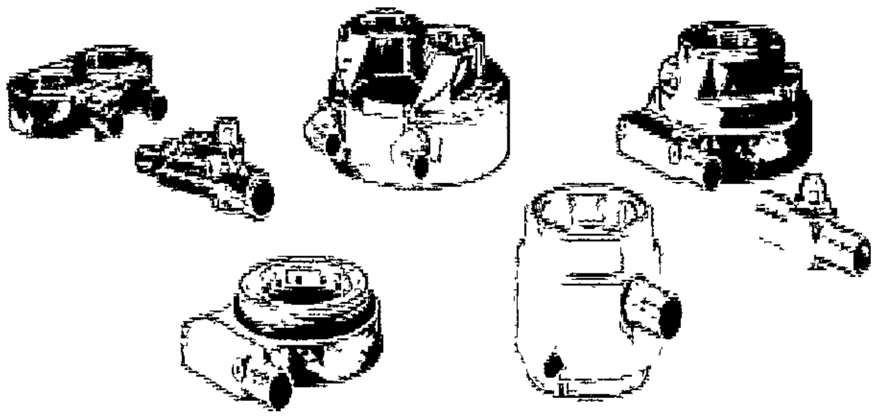


Figure 2.8: Examples design of CNG mixer

2.9 Application in CNG mixer

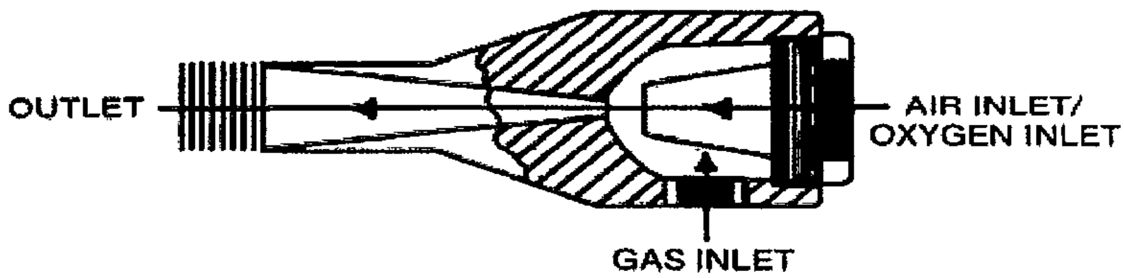


Figure 2.9: Air flow in the CNG mixer

Higher pressure air or oxygen is brought into the mixer; it must pass through the jet. Size of jet controls the amount of air capable of entering the mixer chamber. The fuel gas enters unrestricted into the mixing chamber. Then the pressure of air pushing through the jet mixes the gas together and forces them out through the throat at the proper ratio.

CHAPTER 3

3.1 Introduction

In this chapter 3, contains the methodology and the flow chart of the project progression that have been handle from the beginning until finishing of the final year project from design the CNG mixer by using the SOLIDWORK software and then analyze the design by using COSMOS Flow Works software to know the air flow and the mixing of the air and fuel calculation until get the stoichiometric ratio which mean the mixer mixing the air/fuel in the optimum condition to achieve the highest performance.

The flowchart of project progress

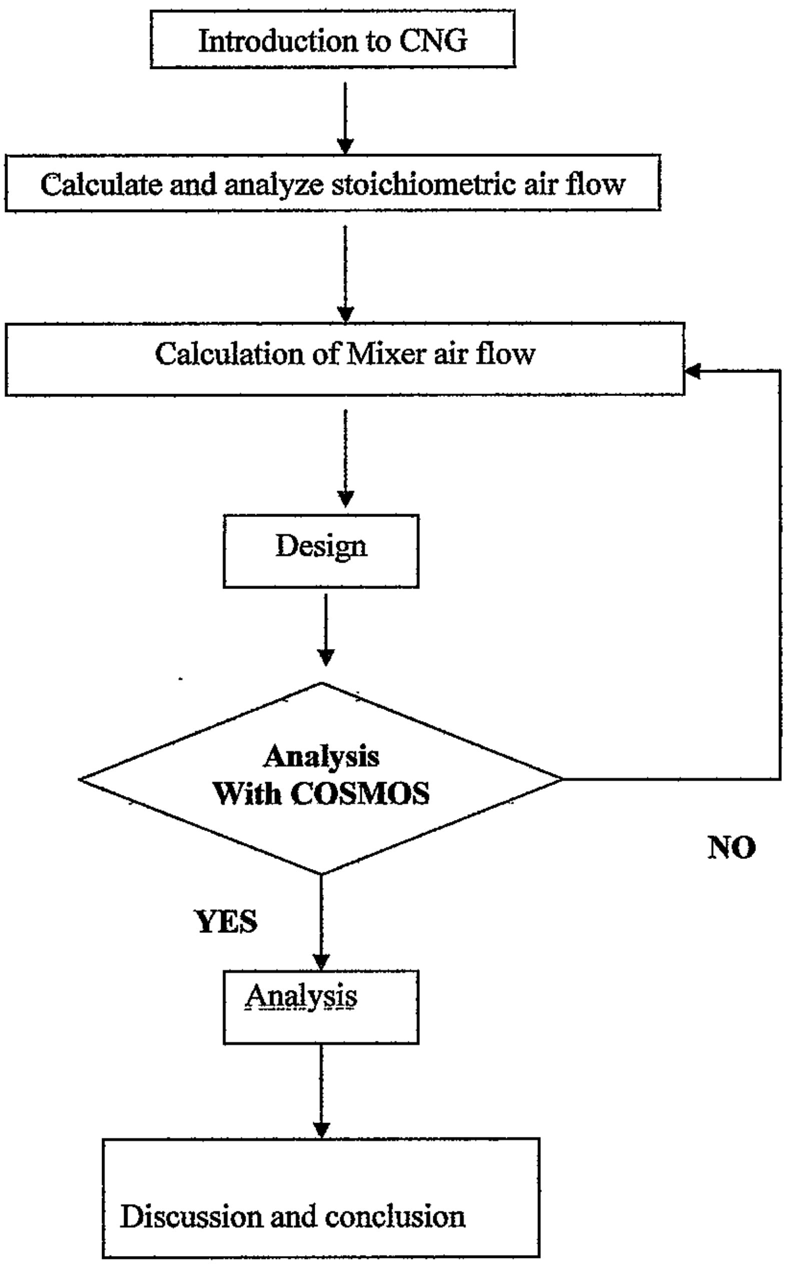


Figure 3.1: Flow chart of project

3.2 Design of the Mixer

A mixer basically is a device in which the air and gas flowing into the engine. It is used in alternative fuel systems to generate a vacuum signal to the regulator that is proportional to the amount of air flowing through the mixer, the regulator the provides the required amount of fuel to the mixer when it is mixed with the air and delivered to the engine. The mixer is usually installed just upstream of the throttle valve. Mixer is selected based on the airflow capacity required to supply the engine with adequate intake air over the range of anticipated engine operating conditions.

For difference engines, the mixer has to design differently to achieve maximum performance. The size is an importance parameter in the design of a mixer. If the mixer is too small, it will limit the development of engine maximum power. Engine could no longer respond to increase of throttle opening when the mixer begins to limit the amount of air entering the engine. The wider throttle could not increase the airflow to the engine because of the mixer restriction. The engine will never achieve it maximum operation point. In the other hand, if the mixer is over design (too large for the engine requirement), poorly controlled manifold vacuum will develop at idle. Difficulty will also occur when low engine speed due to the less fuel suction by the orifice. Meanwhile, the engine maybe always operates at lean condition, which will increase the burning temperature especially when high load operation. Engine starting may also be difficult with the over size mixer.

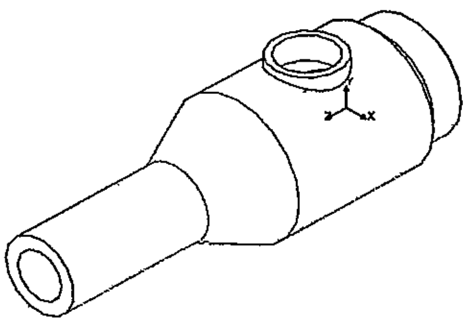
For normal passenger cars that engine never or very few operate with wide open throttle can equipped with a slightly undersize air/fuel mixer since this improved the engine starting and low speed performance.

As the venturi burner type shape was design, many ideas were thought for the shape of the mixer. These shapes are as shown in figure below. The shapes were in development stage, where a constant improvement of the previous design was made. Each shape was discarded until a final acceptable design was reached.

Figure 3.1 shows the design of the inlet of the air that is called jet. These parts were assembling to the main part of the mixer. This part was designed for the main function that is to create an angle to force the air flow through this part for differentiate the pressure from the outer wall and the inner wall same as the theory of Bernoulli equation. Then the part a) and b) were assembled to create the full design of the mixer.

a)

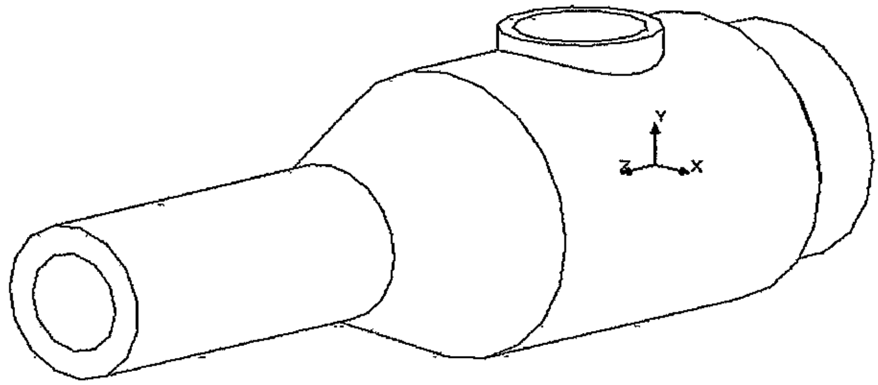
Part 1



b)

Part 2

Figure 3.2: The concept model



Assemble part

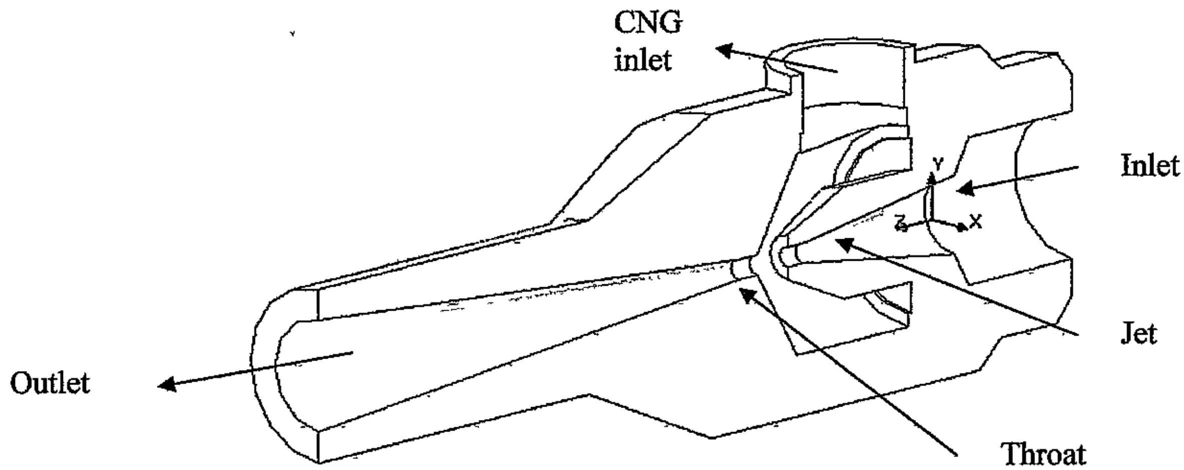


Figure 3.3: The part name of the mixer

3.3 Simulation Using CFD (Computational Fluid Dynamic)

Before the mixer being fabricate, a model of the real situation when the air and the compressed natural gas flow through the mixer can be made to study the mixing characteristics of the mixer, by the means of computer simulation that do finite volume analysis using numerical methods.

As technology advances forward and the world is heading towards Information Technology, more finite volume analysis computer software become available in the market for the convenience of the researchers, manufacturer and others user. This software simulates the condition of airflow in the computer model and the results can just be available in short time, depending on the computer being used.

The used of computer simulation has a few advantages; time can be saved, cost least, less space required and is quite easy to learn. In this report, testing on a computer model of a CNG mixer was done using software that is COSMOS flow works.

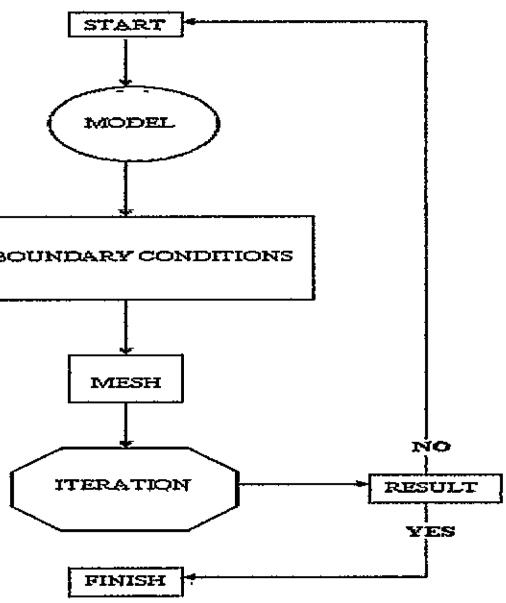


Figure 3.4: The flow Chart of the COSMOS Flow Works

3.4 Stoichiometric Air/Fuel Ratio

The design must be follow the proper parameters to make sure the mixing of air and fuel is 17.4 ratios that we call stoichiometric ratio which means the mixing of the CNG and air achieve the most efficient mixing ratio. This stoichiometric ratio also we can get from chemical composition of methane (CH4) and air which is oxygen (O2). The chemical composition of methane and oxygen is as below:

Methane = CH4

Oxygen = O2

And the atomic masses of interest are:

Carbon (C) = 12

Hydrogen (H) = 1

Oxygen (O) = 16

The balanced chemical equation for complete combustion of methane is as follow:

$$CH4 + 2O2 \rightarrow CO2 + 2H2O$$

The molecular mass of CH4 is:

$$(12 X 1) + (4 X 1) = 16$$

The molecular mass of 2O2 is:

$$(2 X 16 X 2) = 64$$

Therefore the oxygen to methane ratio is 64:16 or 4:1. This means 4 kilogram of oxygen need for completely burn 1 kilogram of methane. Air contains 23 percent of oxygen by mass, which means 1 kilogram of air contains 0.23 kilogram of oxygen. Besides, there is 1 kilogram in 4.35 kilogram of air.

The ideal air/fuel ratio for complete combustion of methane is 4 x 4.35 = 17.4: 1

3.5 Theoretical Calculation

Applying Bernoulli Equation in the mixer basic designed,

Bernoulli Equation:

$$\frac{P}{\rho g} + \frac{V^2}{2g} + Z = \text{Constant}$$

$\frac{P}{\rho g}$ = Energy of pressure

$\frac{V^2}{2g}$ = Kinetic energy

Z = Potential energy

Assumption made in the Bernoulli Equation:

- There is no friction between fluid and the wall of the tube
- The density of the fluid is fix
- The flow is fix

* If the fluid flows one point in a tube to another point in the same tube, the equation:-

1) $$\frac{P_1}{\rho g} + \frac{V_1^2}{2g} + Z_1 = \frac{P_2}{\rho g} + \frac{V_2^2}{2g} + Z_2$$

2) $$\frac{P_1}{\rho g} - \frac{P_2}{2g} = \frac{V_2^2}{2g} - \frac{V_1^2}{2g} + (Z_2 - Z_1)$$

* In the CNG mixer, the effect of potential energy can be neglected due to the differences of height of mixture. If V_1 is the velocity of air in the atmosphere at the intake of the mixer, V_2 is the air velocity at the mixer orifice, the value of V_1 if assume as 0 due to the volume of the air at atmosphere is too large. So that, the equation:-

$$\frac{(P_1 - P_2)}{\rho g} = \frac{V_2^{\,2}}{2g}$$

Thus, $V^2 = \dfrac{2(\Delta P)}{\rho}$

V = Air velocity in the mixer orifice
ΔP = Pressure drop at the mixer orifice
ρ = Density

Mass flow rate, m is the quantity of mixture in mass that flows across a cross section area in a unit of time.

$$m = \rho Q$$

Where,

m = mass flow rate
ρ = density
Q = volume flow rate

Therefore, the mass flow rate of the air flow through the mixer can be calculated as below:

$$m_a = A_a \, . \, \rho_a \, . \, v_a$$

Where,

m_a = the mass flow rate of air
A_a = the cross section area where air flow through
ρ_a = the density of air
v_a = the velocity of air flow

* According to Heywood (1988), the mass of the air inducted into the cylinder per cycle is;

$$m_a = \eta_v \rho_a V_o$$

m_a = flow rate of air

η_v = volumetric efficiency

Vo = initial volume

3.6 Flow Calculation

The general mixer equation is derived from the equations for air and fuel flow. The calculation is base on a 1.5L engine with in-line four cylinders. The maximum speed of the engine is 6500rpm

Table 3.1: Engine specification for 1500cc engine

Type engine	1.5L
Displacement cc	1487
Compression ratio	10.5
No of cylinder	4
Bore (mm)	78.5
Stroke (mm)	82

The mixture flow rate, Q required when the engine is running at 6500rpm can be estimated from the equation as below:

$$Qa = \frac{\eta_v N D}{2} \times 4$$

Where;

Qa = required engine flow rate (m^3/s)

η_v = Volumetric efficiency (85%)

N = engine speed (rpm)

D = engine displacement (m^3)

Assume that volumetric efficiency is 0.85,

$$Qa = \frac{0.85(6500)\ (1487 \times 10^{-6)} \times 4}{2}$$

$= 16.43\ m^3/min$

The mixer needs to supply 16.43 m^3/min air/fuel mixture into the engine when the engine is running at 6500rpm to provide satisfactory engine performance.

Compression ratio

For 1.6L engine:

$r_c = 10.5$

$$r_c = \frac{Vs + Vc}{Vc}$$

$$10.5 = \frac{Vs}{Vc} + 1$$

$$Vs = 9.5\,Vc$$

Calculation on density of air in a tube

Pressure, P= 169325 pa
= 169.325 kpa

Tube Temperature, $T = 20.2^0C$
$= (20.2 + 273)\ K$
$= 293.2K$

Ideal gas constant, R = 287 J/kg.K

Air density:

$$\rho = \frac{P}{(T \times R)}$$

$$= \frac{1.69325 \times 10^5 N/m^2}{(293.2K \times 287 J/kg.K)}$$

$\rho = 2.0122$ kg/m^3

Basic flow rate of engine

For 1 cylinder;

Qa = 7.7 L/s

For 4 cylinder;

Qa = 7.7 x 4

Qa = 30.8 L/s

Volumetric efficiency

Assume 0.85;

$$0.85 = \frac{Vo}{Vs}$$

$$Vo = 0.85 \ Vs$$

* For stoichiometric mixture, the air-fuel ratio is set at 17.4

ρ_a = 2.0122 kg/m3 (Density air)

ρ_f = 0.55 kg/m3 (Density fuel)

$$\text{AFR} = \frac{Q_a \rho_a}{Q_f \rho_f}$$

$$17.4 = \frac{30.8(2.0122)}{Q_f(0.55)}$$

Q_f = 6.476 X 10^{-3} m^3/s

<u>The mass flow rate</u>

$$Ma = \rho_a Q_a$$
$$= 2.0122 \times 7.7 \times 10^{-3} \times 4$$

$$Ma = 0.062 \text{ kg/s}$$

$$M_f = \rho_f Q_f$$
$$= 0.55 \times 6.476 \times 10^{-3}$$

$$M_f = 0.0035618 \text{ kg/s}$$

<u>The Air/Fuel ratio</u>

$$AFR = \frac{Ma}{Mf} \ @ \ \frac{Va}{Vf}$$

3.7 Analysis

Analysis on the CNG mixer air/fuel ratio if it achieve the highest performance if the engine running on CNG and also compared with the previous study on the CNG mixer and also make sure the pressure loss is not in a large amount if the air flow through the mixer and if the pressure loss too high, which mean the mixer is not proper in mixing the air and fuel.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Introduction

As technology advances forward and the world is heading towards information technology, more and more finite volume analysis computer software become available in the market for the convenience of the researchers, manufacturers and other users. This software simulates the condition of airflow in the computer model and the results can just be available in short time, depending on the performance of the computer that being used.

The used of computer simulation has a few advantages that are time can be saved, cost becomes lesser, less space required and is quite easy to learn. In this report, testing on a computer model of a CNG mixer was done by using software named COSMOS Flow Works.

4.2 Geometry Setup

The analysis has been done to the many variable of dimension of the mixer and the air flow has been analyze and there are many difference that we can obtained from the analysis which is the mixture ratio, the mass fraction of the air flow at the CNG inlet and at the jet of the mixer, the mass flow rate of air and methane and last we can obtained the volume flow rate of air and methane. These are the dimension of the first model of the CNG mixer;

Overall length	:	80.80mm
Overall height	:	28.13mm
Diameter of CNG inlet	:	10.77mm
Diameter of air inlet	:	12.32mm
Diameter of mixture outlet	:	9.360mm

Besides these basic dimension, the main different of these mixers model is the diameter of the air inlet at the end of the jet and the throat diameter from the inner wall of the mixer. The diameters are as below:

First model	: Jet	=	1.66mm
	Throat	=	1.66mm
Second model	: Jet	=	1.66mm
	Throat	=	3.44mm
Third model	: Jet	=	3.42mm
	Throat	=	2.84mm

4.3 Boundary Conditions

After the geometry of the mixer had been set up, in order to analyze the CNG mixer models, the boundary conditions of the analysis must be calculated and specified and the result from the calculations will concentrate on. The outlet volume flow rate and the pressure must be calculated and specified by the users.

4.4 Analysis in COSMOS Flow Works

After the designed of the CNG mixer is finished, the design is transferred to COSMOS Flow Works for analysis. Before the analysis was done, we have to set the boundary condition of the air and methane. This is because the boundary condition is important to create and in forming the flow in the mixer. These are some boundary condition that has been setup during the analysis:

The outlet volume flow	:	0.2738 m^3/s
Methane pressure	:	151325 pa
Air pressure	:	169325 pa
Concentration of Methane at the air inlet	:	0 percent
Concentration of air at the air inlet	:	100 percent
Concentration of Methane at the CNG inlet	:	100 percent
Concentration of air at the CNG inlet	:	0 percent

After keying in these input parameters, calculation were done with 227 iteration before the result were out.

4.5 Result from COSMOS Flow Works Simulation

After analyze the design by using COSMOS Flow Works, there are two types of boundary condition that can be obtained which are the result with variable parameters and pressure.

4.5.1 Effect on Diameter

These are the result of computer simulation using COSMOS software with the variable diameter of the throat and the jet. For the first model refer to figure (4.1) from the simulation, the mass flow rate of the air is -0.00122892 kg/s and the mass flow rate of the methane is -0.00122892 kg/s. Thus, the A/F ratio which is mass flow rate of air over mass flow rate of methane and this equal to 1. These means that the volume of air and methane which flow through the outlet is same and not compatible with the A/F ratio.

Figure (4.2) shows the result for the second model. The mass flow rate of air is equal to -0.000852849 kg/s and the mass flow rate of methane is -0.00202187 kg/s. The A/F ratio is equal to 0.4218. This ratio also is not compatible with the stoichiometric ratio which is 17.4 (from the calculation). This result means that the volume of methane that flow through the outlet is larger amount than the air volume.

Figure (4.3) shows the result for the third model. From the simulation, the mass flow rate of air is equal to -0.061334 kg/s and the mass flow rate of methane is -0.0035618.This result means that the volume of air that flow through the outlet is larger amount than the volume of methane. The A/F ratio is equal to 17.22 which can consider satisfied with the stoichiometric ratio. Thus, the design for the third model is compatible with the stoichiometric A/F ratio.

4.5.2 Effect on Pressure

These are the result with the simulation using variable pressure of air inlet. For the figure (4.4) shows the air flow by using the pressure of 151325 pa that mean the same pressure as the CNG inlet pressure from the pressure regulator. The color of the outlet mixture also more to brown that means the volume of methane is still larger in the mixture and the mixing contain more to volume of methane than the air volume as the mixing ratio is 0.3889.

Figure (4.5) shows air flow by using the pressure of 160325 pa. As we can see the outlet mixture is more to air volume. The mixing ratio is 6.0789. The mass flow rate of air is -0.00634017 kg/s and the mass flow rate of methane is -0.00104298 kg/s. It shows that the content of volume of air is greater than the volume of methane.

Figure (4.6) shows the air flow by using the pressure of 167325 pa. The outlet mixture is still more to air volume. The mixing ratio is 16.7005. The mass flow rate of air is -0.011889436 kg/s and the mass flow rate of methane is -0.000711921 kg/s.

By increase the air inlet pressure, the content of air flow through the outlet also increases. This is because if the pressure of air is high at the orifice, the less of volume methane can flow and mix with the air.

From the result also we can obtain the pressure drop occur at the mixer orifice. For increase the pressure 9000pa, the pressure drop is 118.322pa and for increase the pressure 7000pa the pressure drop is 39.62pa. The pressure drop decrease because the contains of methane is also decrease. This means by if the methane decrease it is proportional to the pressure drop.

4.6 SWOT Analysis

STRENGTH	WEAKNESS
1) Knowledge in the CNG mixer function and how the mixer works	1) Not expert in using software SOLIDWORK and the simulation by CFD 2) Not enough information about how to design the CNG mixer
OPPURTUNITY	**THREAT**
1) Improve the skill of using the SOLIDWORK software 2) Gain knowledge about the CNG mixer and the advantage by using the CNG as a fuel	1) Ask supervisor or others lecturer that Expertise in this field. 2) Search information about the topics in the internet, magazines or journals

Table 4.1: SWOT analysis

CHAPTER 5

CONCLUSION AND RECOMMENDATION

The characteristic of the air, compressed natural gas and the mixture of air and gas flow in the mixer has been discussed here, with the discussion on theory and later on being proved by computer simulation COSMOS Flow Works. As it has been discussed in this project earlier, air flow is one of the areas that need to be considered seriously when a CNG mixer is designed, as it not only reduce the pollution by automobile vehicle but also improves the vehicle performance.

The engine emissions level is also very important as we designed and create the engine by using methane as a fuel and this will improve the emission as we discussed earlier in the literature review. A high quality mixer should provide the very optimum environment for engine to perform in the optima condition.

In the process of designing the CNG mixer, it can be deducted that the design has reached the objectives. A CNG mixer in the same application as venturi mixer was designed for 1500cc four stroke engine application. A mixer capable of providing a stoichiometric A/F ratio condition.

CFD was a good tool to analyze the mixer and is a form of cost saving and time saving. From the simulation, the dimensions of the design were finalized. A conceptual design was obtained from the CFD simulation.

Lastly, to ensure the testing on the model by using computer simulation method is well being done, the results of the simulation are printed to show the air flow and the result from the simulation.

The recommendation is the mixer need to design like the dimension as state as before to give better mixing ratio of air and methane and to give the highest performance to the engine when running with CNG. There also need some tools like a function same as a pressure regulator to increase the intake air pressure in order to give the better mixing ratio with the methane.

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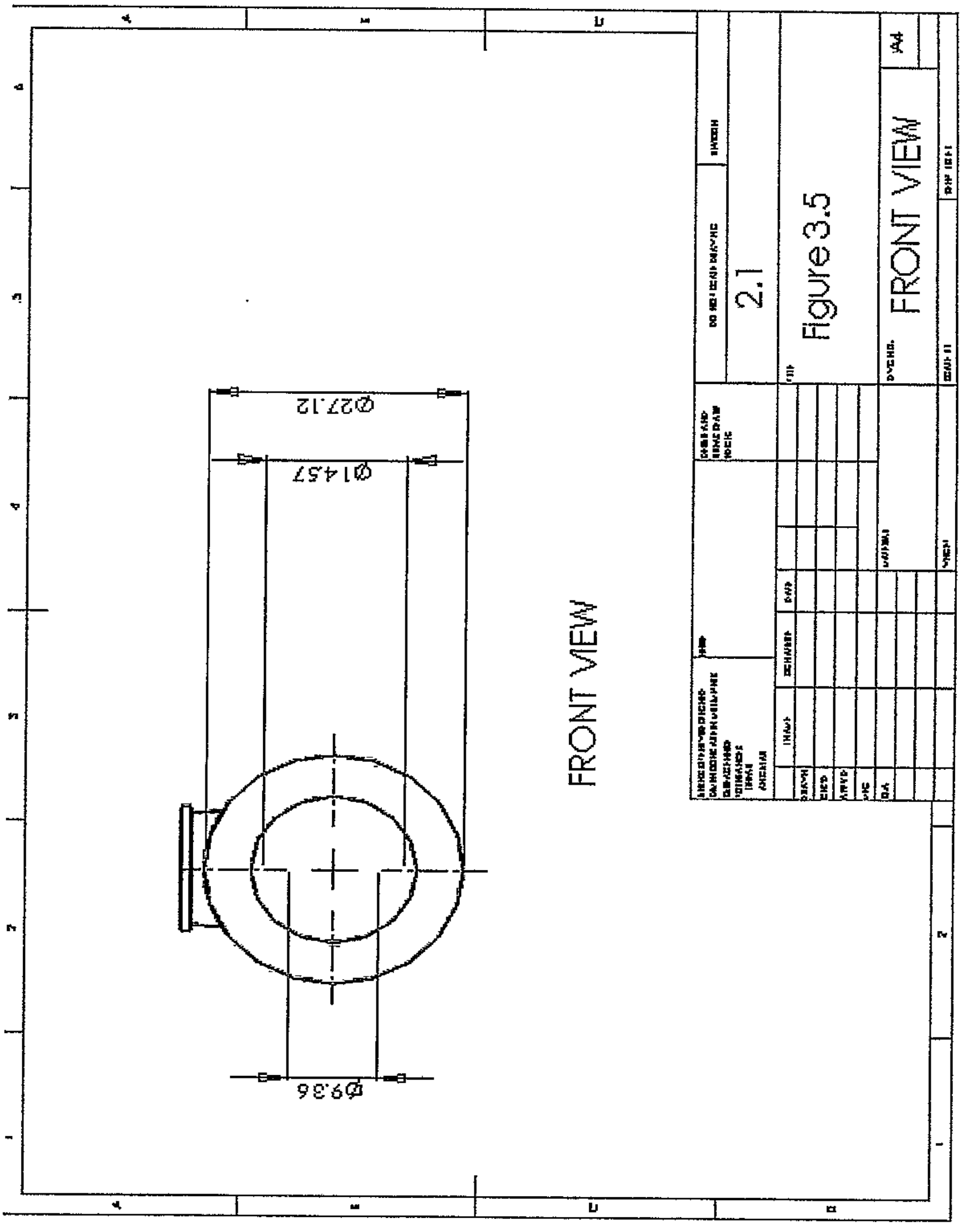
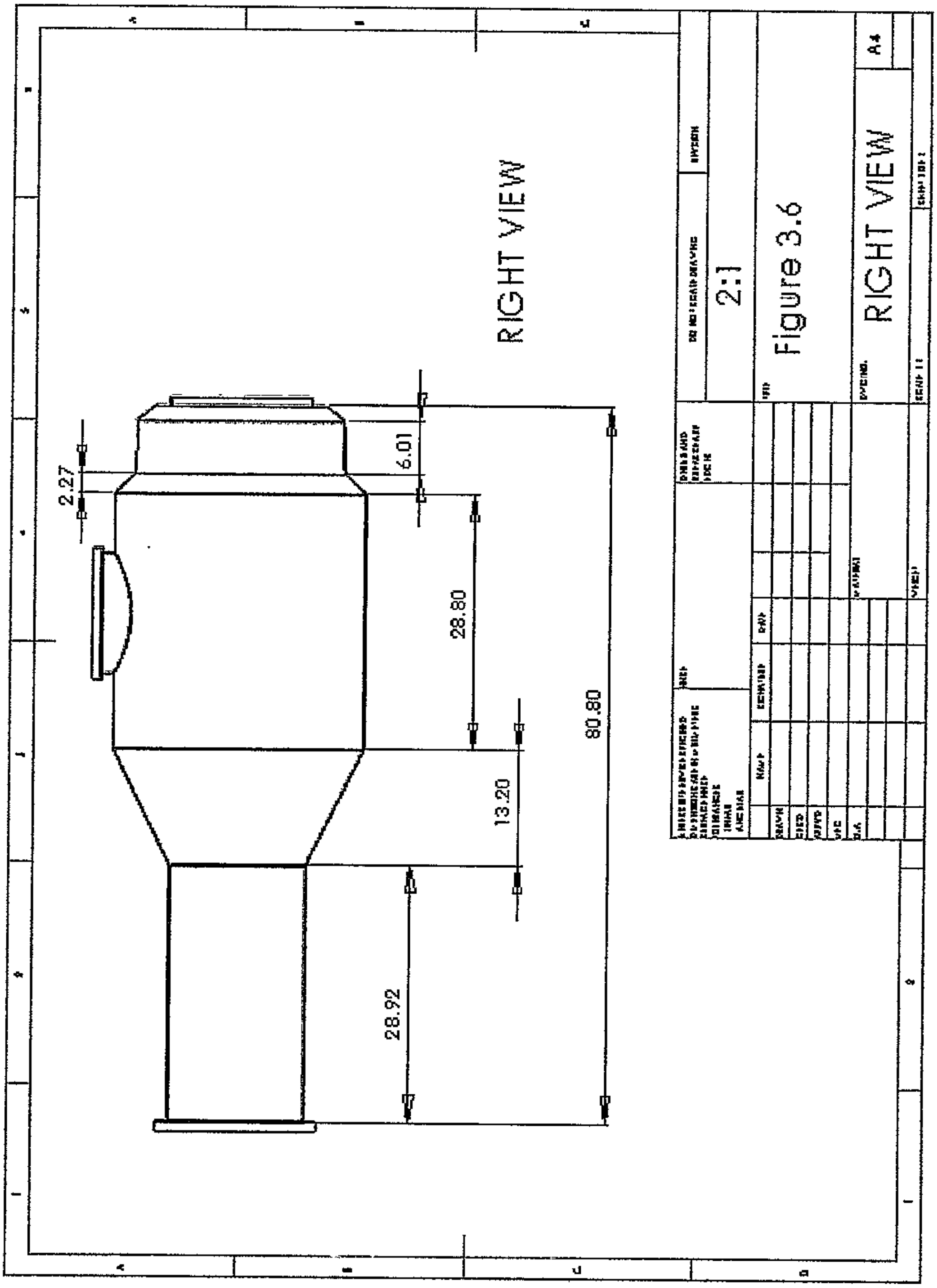
APPENDIX A

	FINAL YEAR PROJECT 2 GANTT CHART														
	Design of A CNG Mixer for 1500cc engine														
	TASK	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
1	Updated the project by reading other journals	■	■	■											
2	Discussion with supervisor			■											
3	Design the CNG mixer				■	■									
4	Design the CNG mixer using a proper dimension						■	■							
5	Analyze the model by using COSMOS flow works							■	■	■					
6	Manual calculation on the air flow through the mixer									■	■				
7	Compared manual calculation with the software calculation										■	■			
8	Complete the result											■	■		
9	Works on the discussion											■	■		
10	Complete chapter 4 until 5												■	■	
11	Show progress to supervisor to finalize													■	
12	Submit logbook, and thesis report to the supervisor													■	
13	Presentation of the FYP 2 to the panels														■

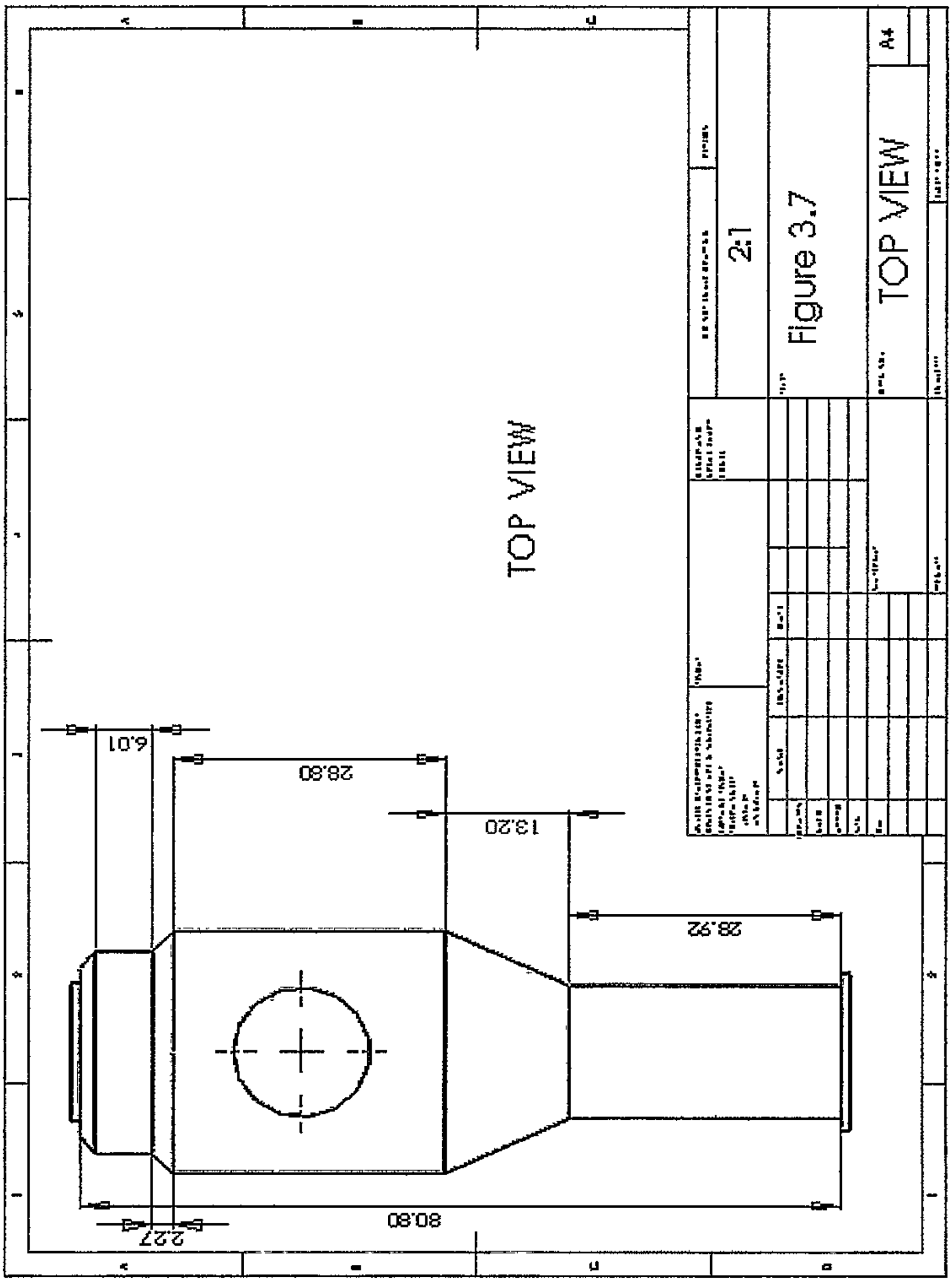
APPENDIX B



APPENDIX C


RIGHT VIEW
2.27
6.01
28.80
80.80
13.20
28.92
2:1
Figure 3.6
RIGHT VIEW
A4

APPENDIX D



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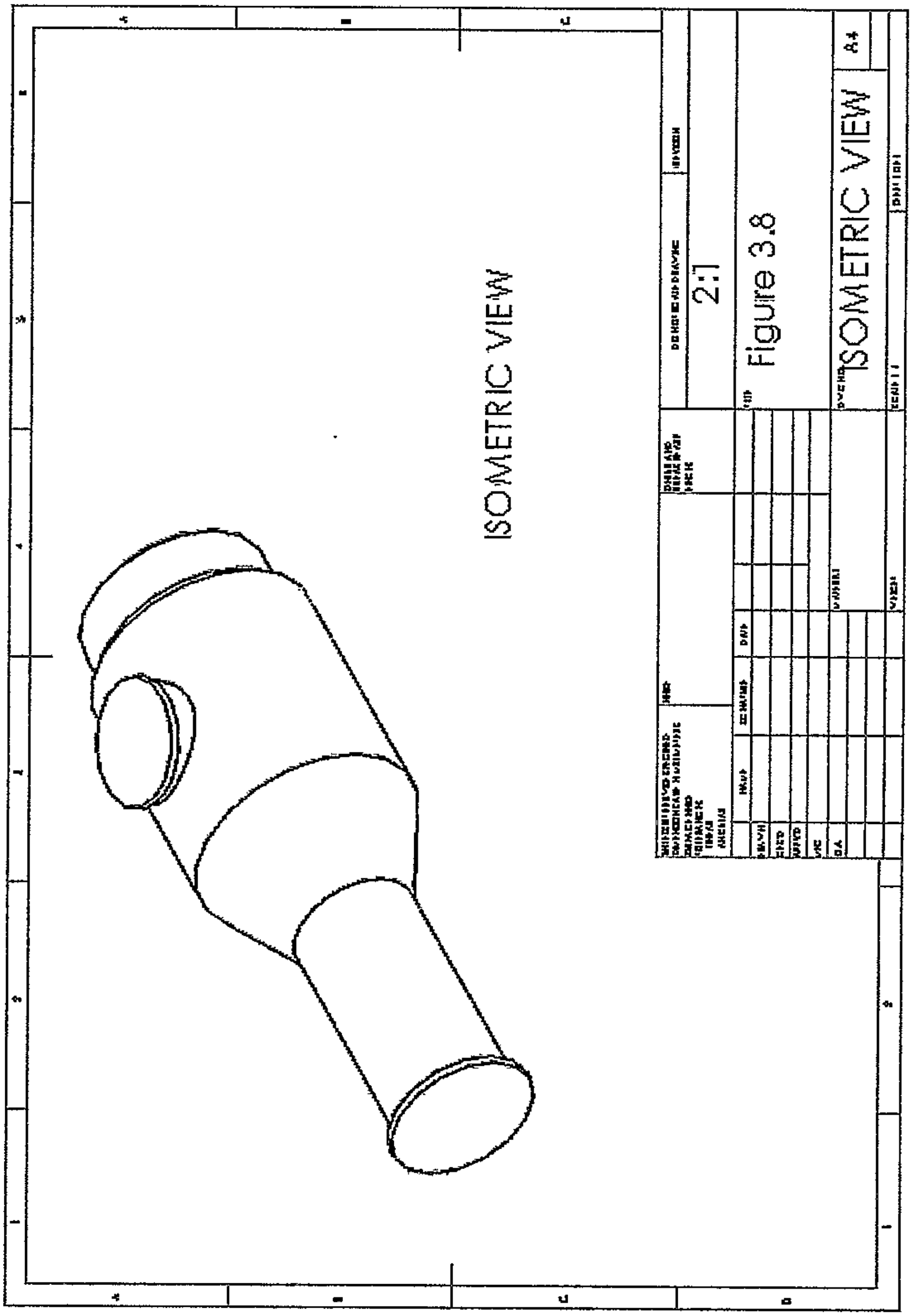

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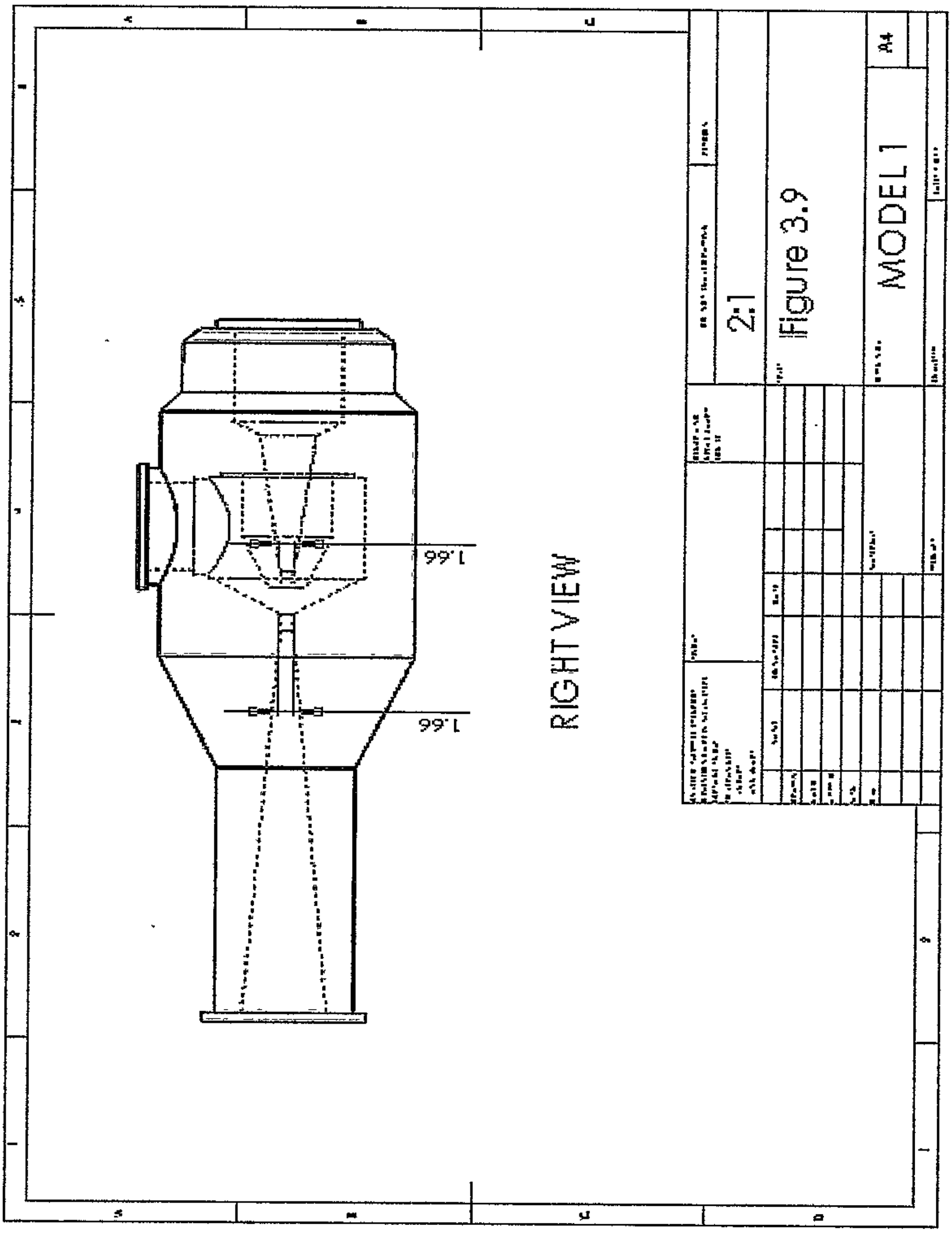

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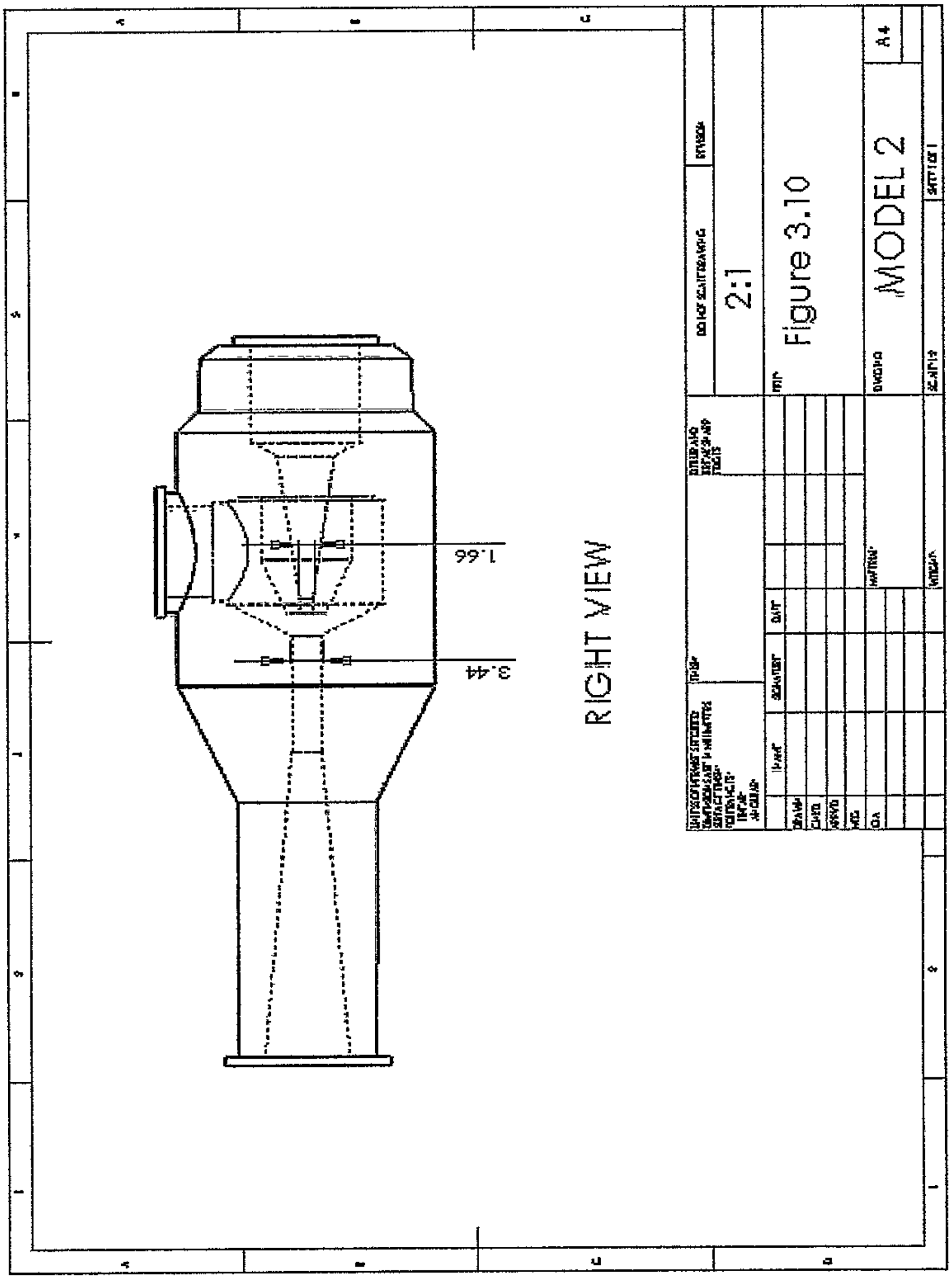

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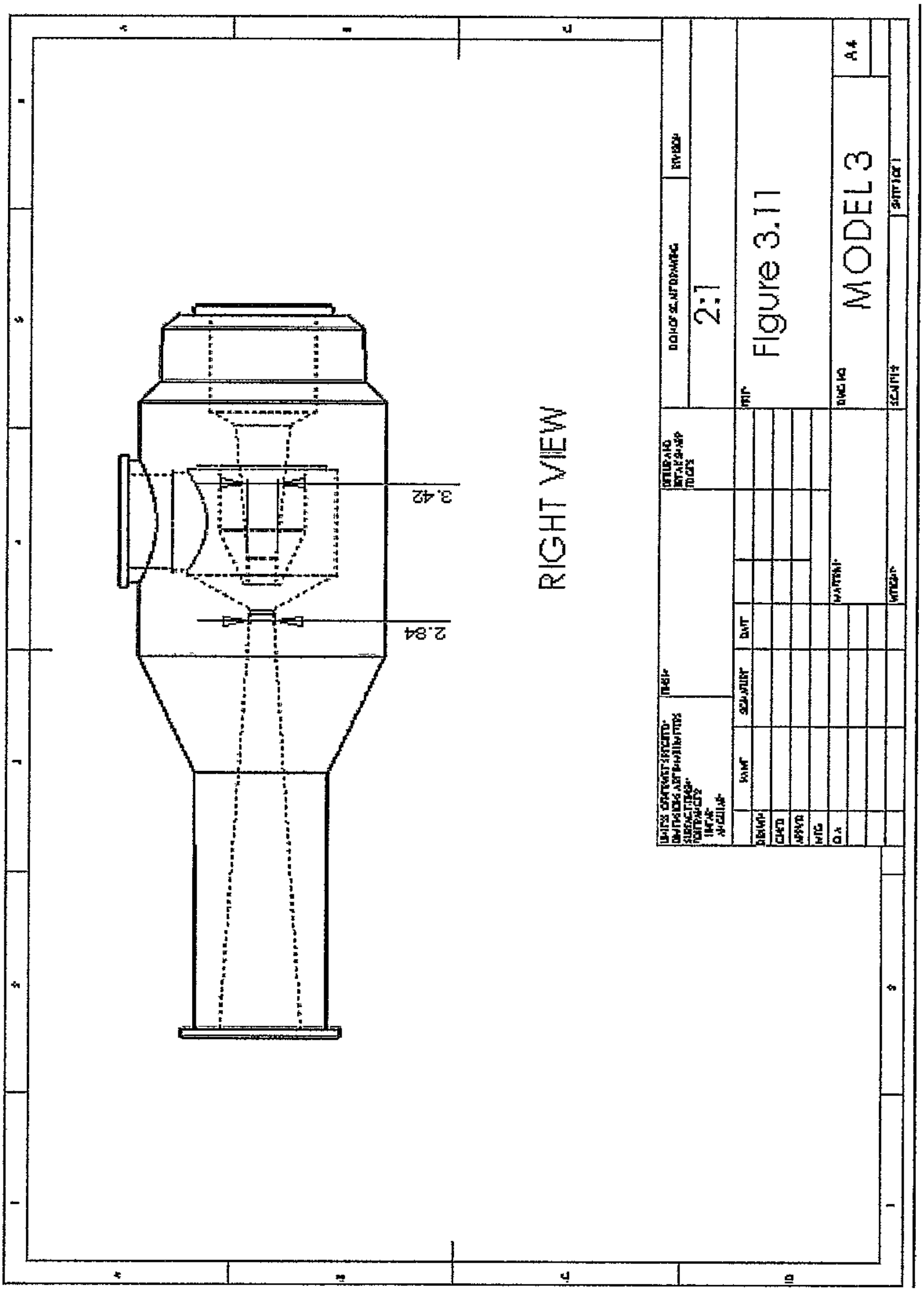

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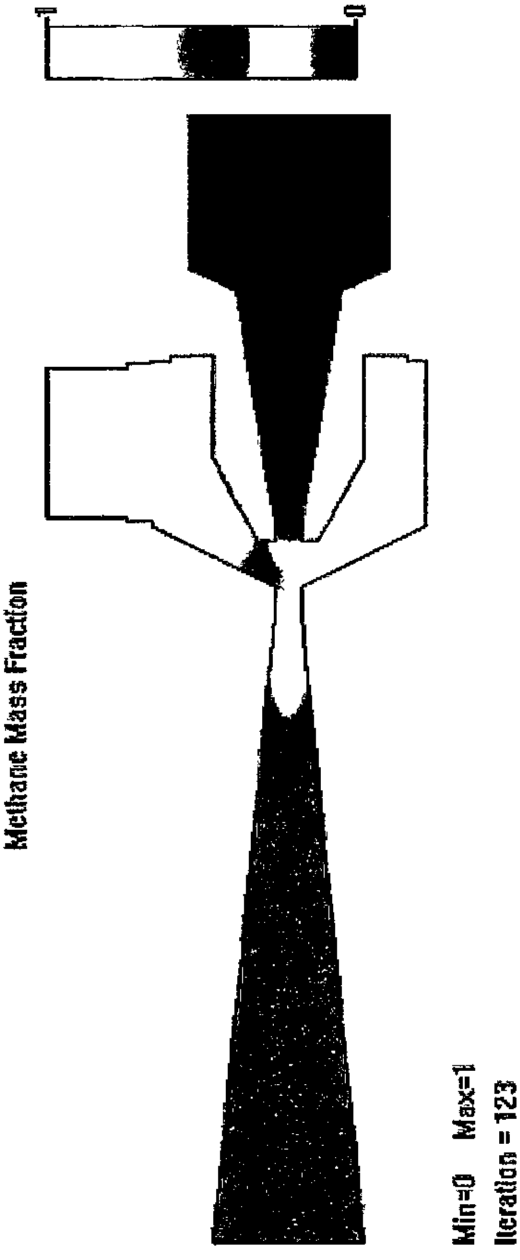
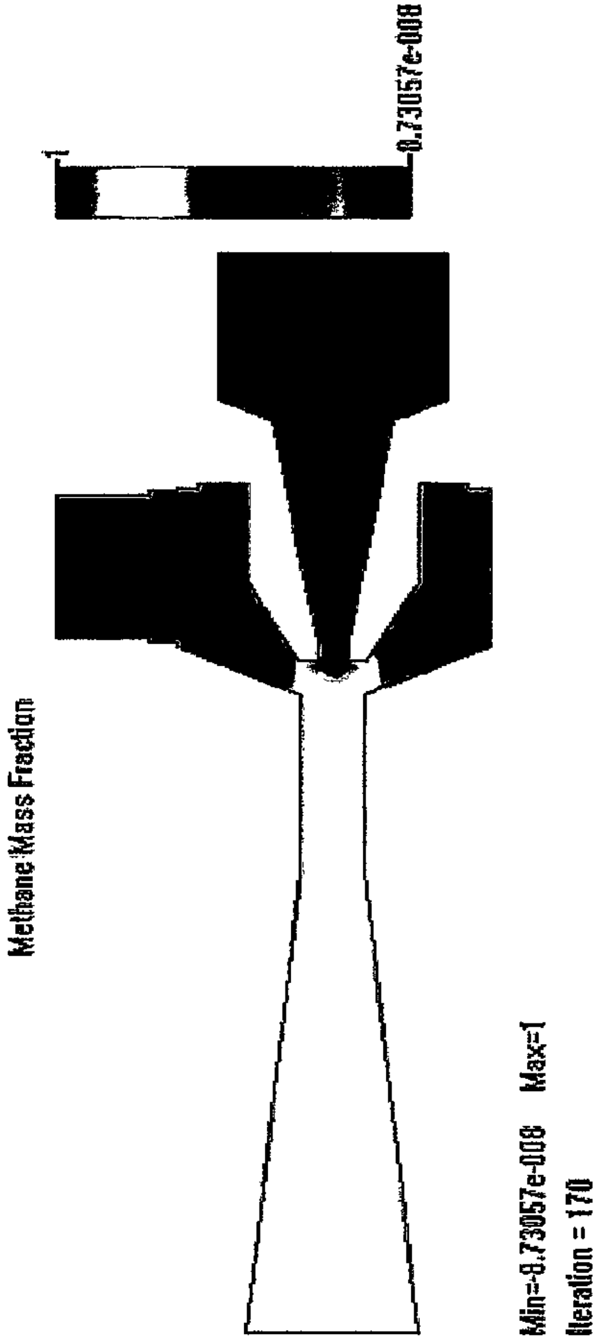


Methane mass fraction for model 1

Figure 4.1

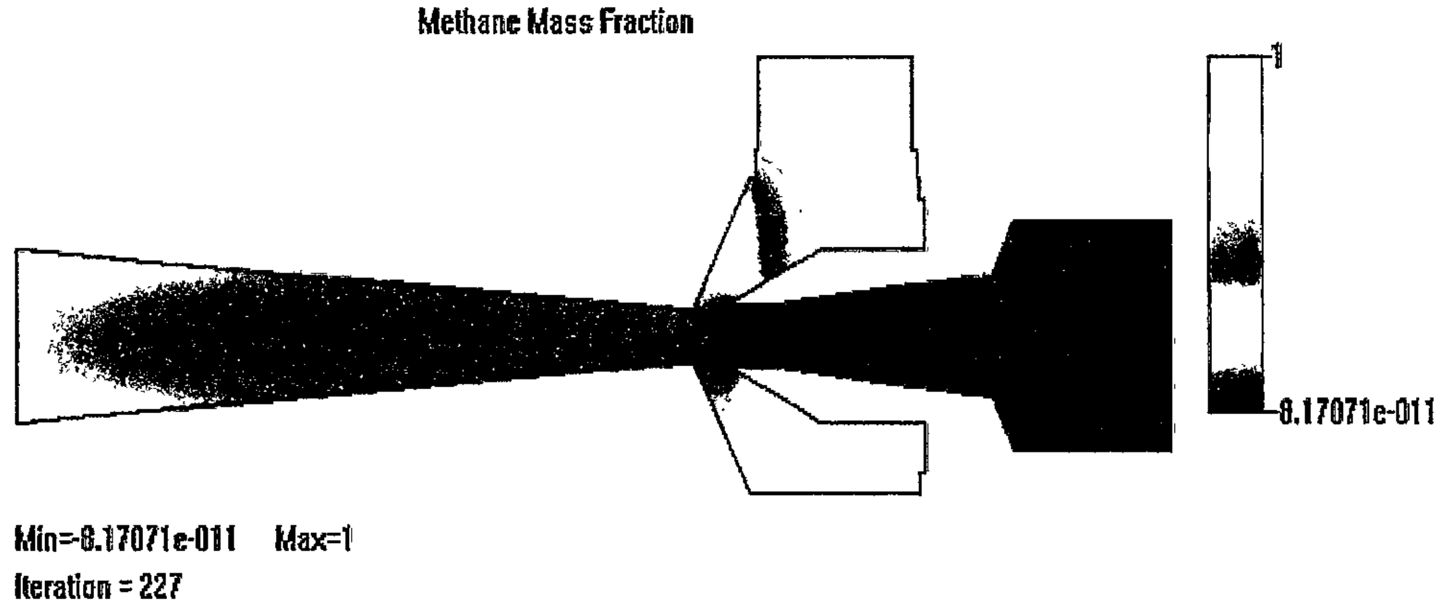
APPENDIX J



Methane mass fraction for model 2

Figure 4.2

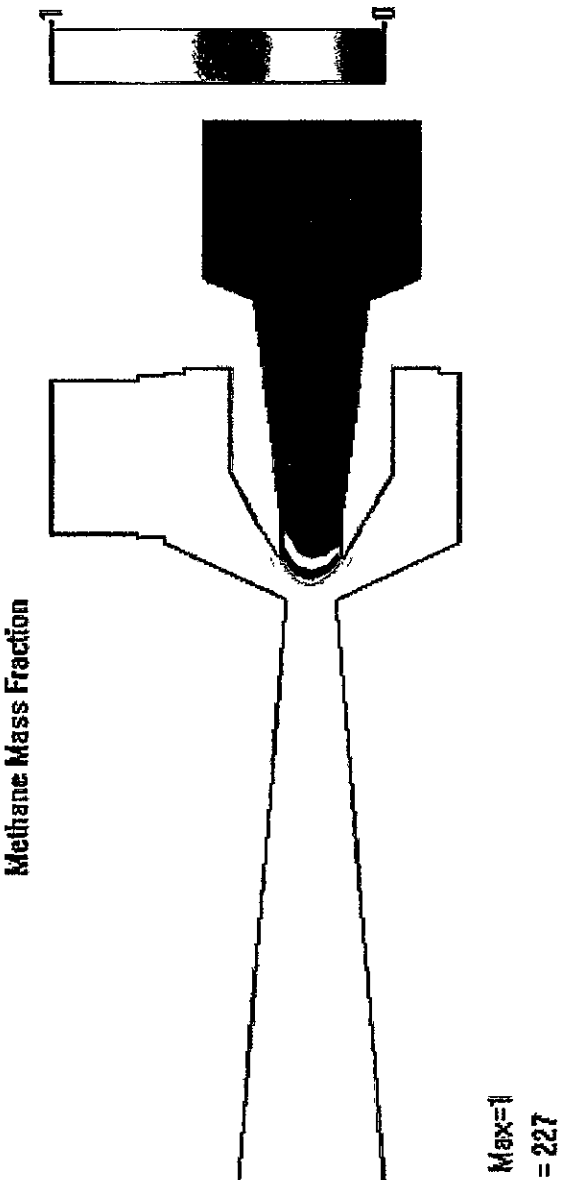
APPENDIX K



Methane mass fraction for model 3

Figure 4.3

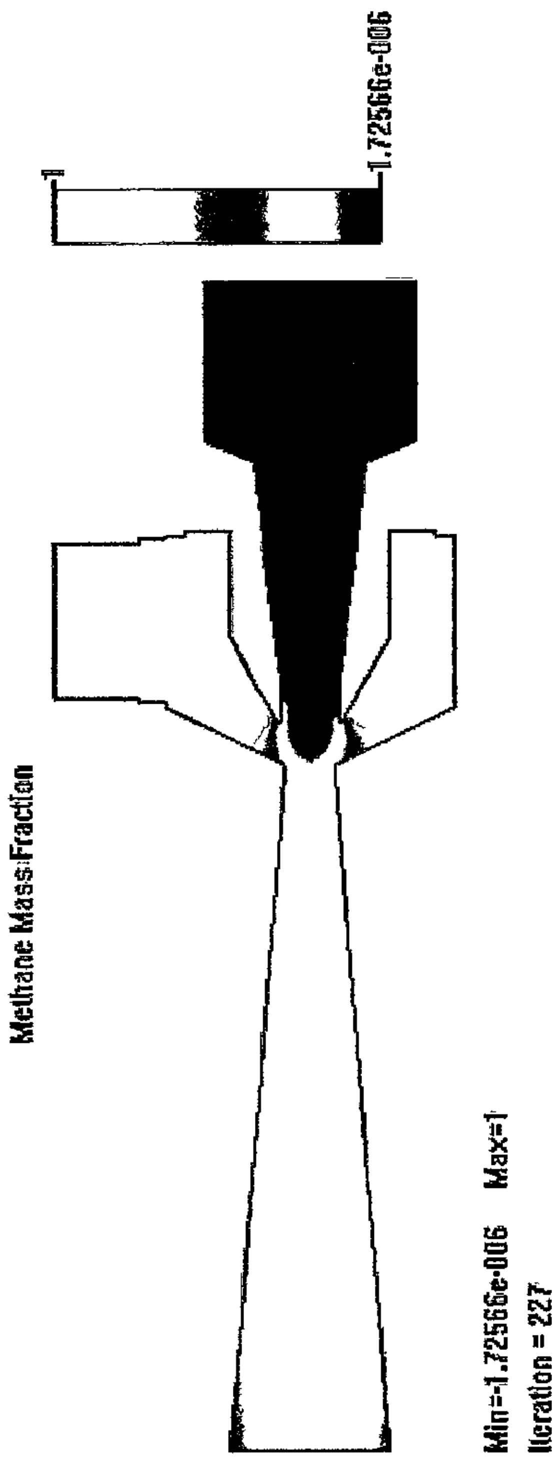
APPENDIC L



Methane mass fraction for pressure 151325pa

Figure 4.4

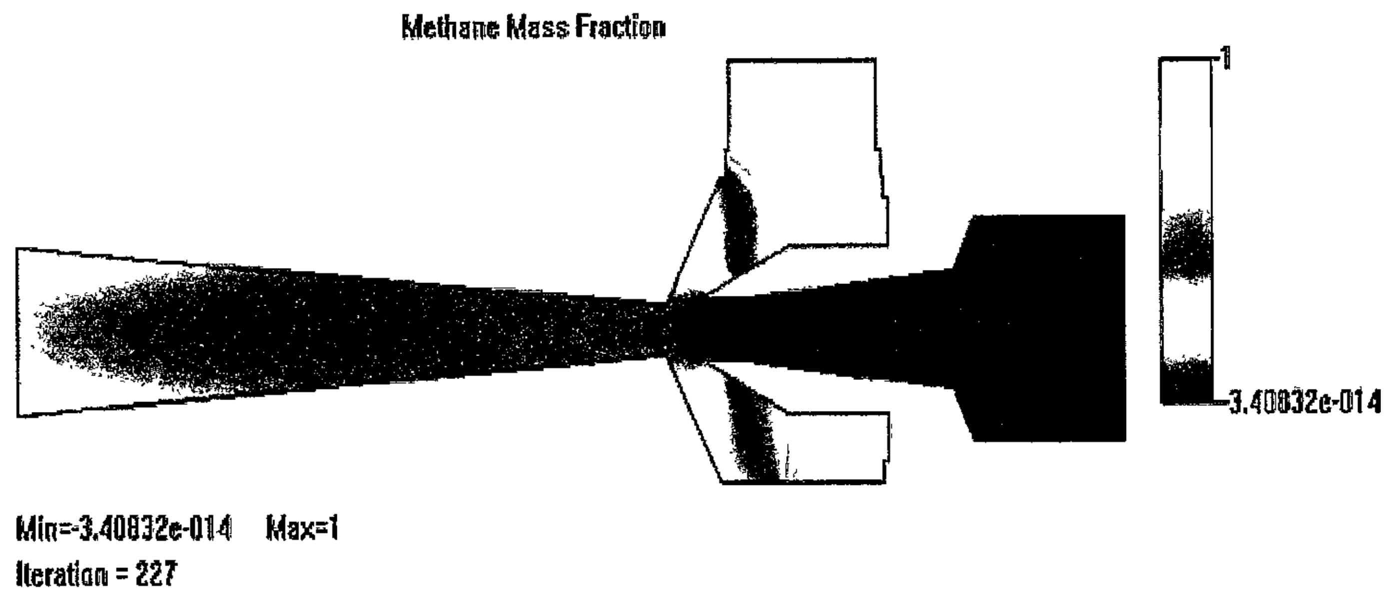
APPENDIX M



Methane mass fraction for pressure 160325pa

Figure 4.5

APPENDIX N



Methane mass fraction for pressure 167325pa

Figure 4.6