THE STUDY OF COMBUSTION CHARACTERISTICS FOR DIFFERENT COMPOSITIONS OF LPG

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ABSTRACT

Varieties of liquefied petroleum gas (LPG) are based on variety composition of propane and butane. The common composition of LPG contains 70% or 60% volume of butane and 30% or 40% volume of propane. However there have some variations of LPG composition as dictated by its usages and applications. Because of the different composition between propane and butane in LPG that used today, it can give different combustion characteristics of the LPG. The objective of this work is to study and analyze the combustion characteristic for different composition of LPG. The scope of this work is to analyze the energy that released which is commonly known as calorific value (CV), to determine the flame speed and to analyze the emission for different composition of LPG. The results get from this research are the calorific value of LPG that contains more butane is higher than one contains more propane. Beside that, the emission from LPG combustion is increased with the number of hydrocarbon in the LPG composition. Finally, the flame speed is decreasing when the composition of hydrocarbon is higher; in other word it decreases when LPG is contains more butane. The LPG that contains higher number of hydrocarbon can give more quantity heat by its combustion but the flame speed from it combustion slower and it also gives a higher effect to environment. The variation of composition in LPG gives an effect to their combustion characteristics. The research of combustion characteristic can optimize if using the sample of LPG that contain the other composition. Beside that, the other combustion characteristic like flammability limit also can be added to see the view of safety aspect when using the different composition of the LPG.

ABSTRAK

Kepelbagaian gas petroleum cecair (LPG) adalah berdasarkan komposisi propana dan butana. Kebiasaannya komposisi LPG adalah diantara 70% atau 60% butana dan 30% atau 40% kandungan propana. Walaubagaimananpun, terdapat beberapa variasi komposisi LPG berdasarkan kegunaan dan aplikasinya. Disebabkan perbezaan komposisi antara propana dan butana di dalam LPG yang digunakan hari ini, ia akan memberikan ciri-ciri pembakaran yang berbeza. Objektif kajian ini adalah untuk mengkaji dan menganalisa ciri pembakaran berdasarkan perbezaan komposisi dalam LPG. Skop kajian ini pula merangkumi menganalisa jumlah tenaga yang dikeluarkan oleh LPG atau juga lebih dikenali sebagai nilai kalorifik (CV), menganalisa halaju api dan juga analisa terhadap sisa pembakaran bagi LPG yang berlainan komposisi. Keputusan yang diperolehi melalui kajian ini menunjukkan nilai kalorifik bagi LPG yang mengandungi komposisi butana yang lebih adalah tinggi berbanding LPG yang mengandungi komposisi propana yang lebih. Disamping itu, nilai NOx yang terhasil daripada pembakaran LPG adalah meningkat berdasarkan bilangan hidrokarbon dalam komposisi LPG. Akhir sekali, halaju inhalan api menurun apabila komposisi hidrokarbon semakin tinggi, dengan kata lain ianya menurun apabila LPG mengandungi lebih banyak butana. LPG yang mengandungi lebih banyak hidrokarbon membekalkan lebih kuantiti haba dalam permbakarannya, tetapi ia turut menghasilkan inhalan yg lebih perlahan disamping kesan yang lebih terhadap alam sekitar. Variasi komposisi LPG memberi kesan terhadap ciri pembakarannya. Kajian mengenari ciri pembakaran LPG boleh dioptimakan dengan menggunakan sampel LPG yang mengandungi komposisi yang berbeza pula. Disamping itu, ciri-ciri pembakaran yang lain seperti had keterbakaran boleh ditambah sebagai pandangan terhadap ciri keselamatan apabila menggunakan LPG yang berlainan komposisi.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS

LPG	Liquefied Petroleum Gas
CV	Calorific Value
NO_x	Oxide of Nitrogen
H_2S	Hydrogen Sulfide
ppm	Part per million

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background Study

Liquefied petroleum gas (LPG) is a mixture of hydrocarbon gases used as a fuel in heating appliances and vehicles. In addition, it is increasingly replacing chlorofluorocarbons as an aerosol propellant and as a refrigerant to reduce damage to the ozone layer [4]. There are three methods for synthesis of LPG. First, LPG is synthesized from syngas. The second method is indirect synthesizing LPG from syngas, synthesis of methanol or dimethyl ether (DME) from syngas, conversion of methanol or DME into hydrocarbon of LPG fraction (olefin and paraffin), and then olefin hydrogenation to LPG. And the last method is semi indirect synthesis of LPG from syngas, synthesis of DME from syngas or methanol and conversion of DME into LPG in presence of hydrogen [1]. LPG is any mixture of several hydrocarbon compounds that are gases at normal room temperatures and pressures but can be liquefied under moderate pressure at atmospheric temperatures. These gases can include, paraffins occurring between ethane (a gas) and pentane (a liquid) and monolefins occurring between ethene and pentene. The paraffins include propane, iso-butane, and butane. The monolefins include propylene, isobutene, 1-butene, and 2-butene. [5]

Varieties of LPG bought and sold in variety composition of propane and butane. The common composition of LPG contains 60% volume of propane and 40% volume of butane. However there have some variations of LPG composition as dictated by its usages and applications [5].

1.2 Problem Statement

Because of the different composition between propane and butane in LPG that used today, it can give different combustion characteristics. So the study of LPG combustion characteristic is important because from the different of combustion characteristic, it will show the different usage and advantages use pure propane, pure butane or mixture between propane and butane in LPG.

1.3 Objective

As was mentioned earlier, the combustion characteristic between pure propane, pure butane ore mixture of propane and butane that use in LPG is different. Therefore, the objective of this work is to study and analyze the combustion characteristic for different composition LPG.

1.4 Scope

The first scope of this work is to analyze the energy that release is commonly known as calorific value (CV) or sometimes called it as a heating value. Calorific value is commonly determined by use of a boy's calorimeter. And then after determine the calorific value of each element; make a comparison between the elements. The second scope of this work is to determine the flame stability. The last scope is to determine the emission for different composition LPG.

CHAPTER 2

LITERATURE RIVIEW

2.1 Introduction

Varieties of LPG bought and sold in variety composition of propane and butane. The common composition of LPG contains 60% volume of propane and 40% volume of butane. However there have some variations of LPG composition as dictated by its usages and applications. Commercial Propane predominantly consists of hydrocarbons containing three carbon atoms, mainly propane (C3H8) [5].

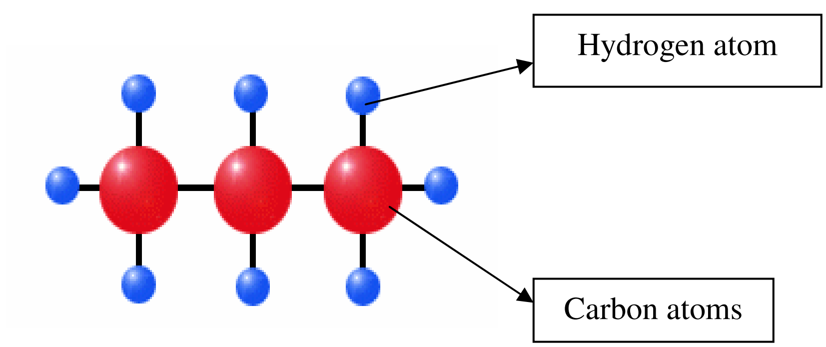

Figure 1.1: Atomic Structure of Propane

Commercial Butane predominantly consists of hydrocarbons containing four carbon atoms, mainly n- and iso-butanes (C_4H_{10}).

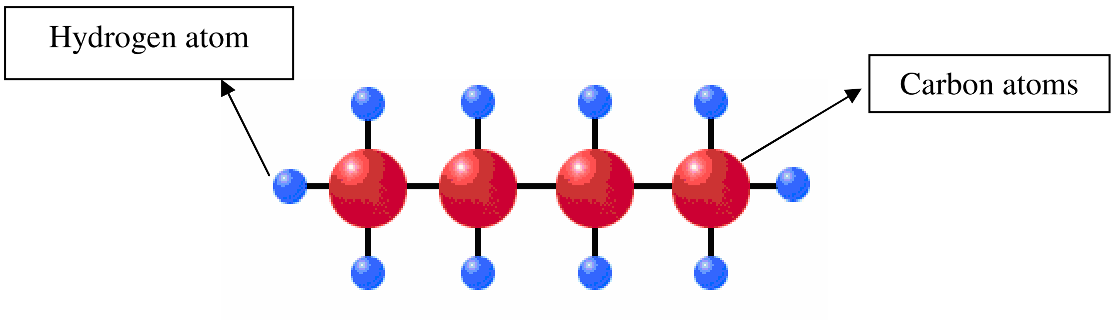

Figure 1.2: Atomic Structure of n-Butanes

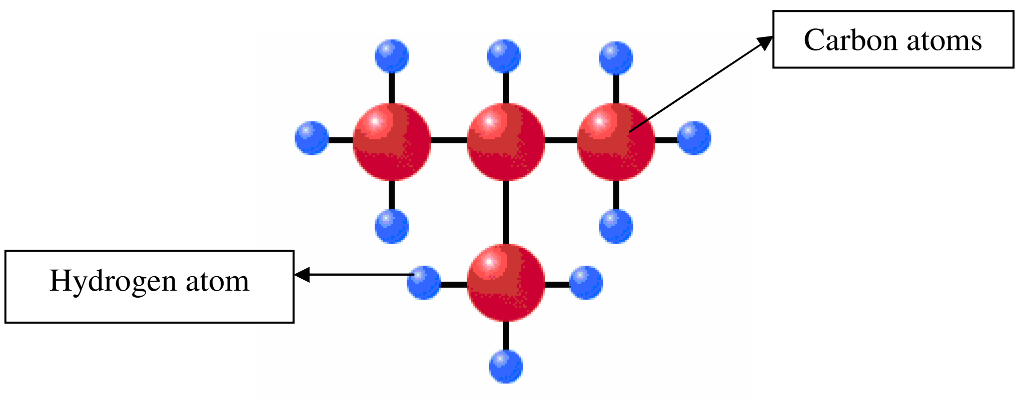

Figure 1.3: Atomic Structure of iso-Butanes

Propylene and butylenes are usually also present in small concentration. A powerful odorant, ethanethiol, is added so that leaks can be detected easily. The international standard is EN 589 [6].

2.2 Physical Properties

At normal temperatures and pressures, LPG will evaporate. Because of this, LPG is supplied in pressurized steel bottles. In order to allow for thermal expansion of the contained liquid, these bottles are not filled completely; typically, they are filled to between 80% and 85% of their capacity. The ratio between the volumes of the vaporized gas and the liquefied gas varies depending on composition, pressure and temperature, but is typically around 250:1 [4].

The pressure at which gas becomes liquid, called its vapor pressure, likewise varies depending on composition and temperature; for example, it is approximately 220 kPa (2.2 bar) for pure butane at 20 °C (68 °F), and approximately 2.2 mPa (22 bar) for pure propane at 55 °C (131 °F) [4].

The vapor pressure of a mixture of the two products can be found in the table below [6]:

Table 1.0: Vapor pressure of a mixture propane and butane

Vapor Pressure (psig)							
Mixture	Propane (C_3H_8) (%)		100	70	50	30	0
	Butane (C_4H_{10}) (%)		0	30	50	70	100
Temperature (^0F)		-44	0	0	0	0	0
		-30	6.8	0	0	0	0
		-20	11.5	4.7	0	0	0
		-10	17.5	9	3.5	0	0
		0	24.5	15	7.6	2.3	0
		10	34	20.5	12.3	5.9	0
		20	42	28	17.8	10.2	0
		30	53	36.5	24.5	15.4	0
		40	65	46	32.4	21.5	3.1
		50	78	56	41	28.5	6.9
		60	93	68	50	36.5	11.5
		70	110	82	61	45	17
		80	128	96	74	54	23
		90	150	114	88	66	30
		100	177	134	104	79	38
		110	204	158	122	93	47

Note that the evaporation temperature is not the only parameter that influence on the evaporation of the propane butane mixture. The evaporation requires heat and if the heat transfer to the liquid gas is limited, the liquid will be under cooled and the evaporation reduced. Larger consumes requires in general heat exchangers fueled with hot water, electric heater or combustion of the propane butane mix itself. Smaller amounts of consumption require containers with efficient heat transfer. For example composite container provides less heat transfer compared with steel containers [6].

2.2.1 Propane Butane Mixture Vapor Diagram – psig [6]

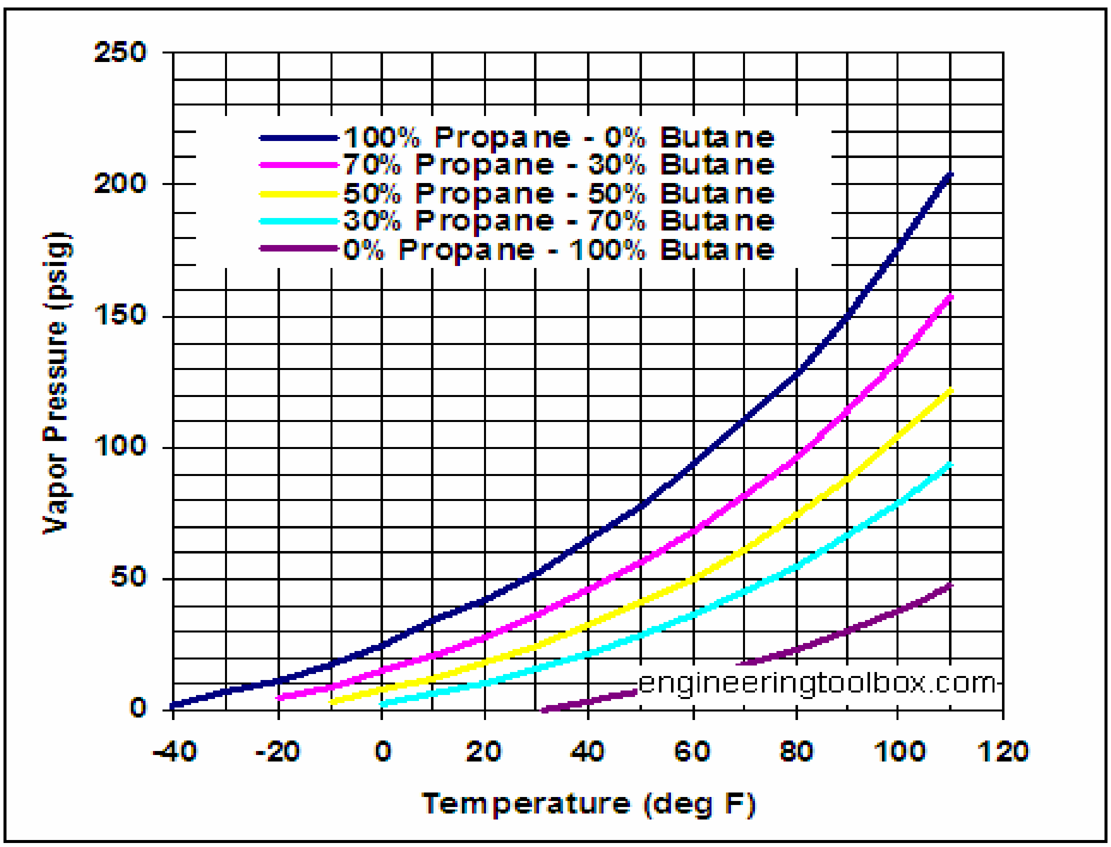

Figure 2.1: Propane Butane Mixture Vapor Diagram

2.2.2 Propane Butane Mix Vapor Diagram – bar [6]

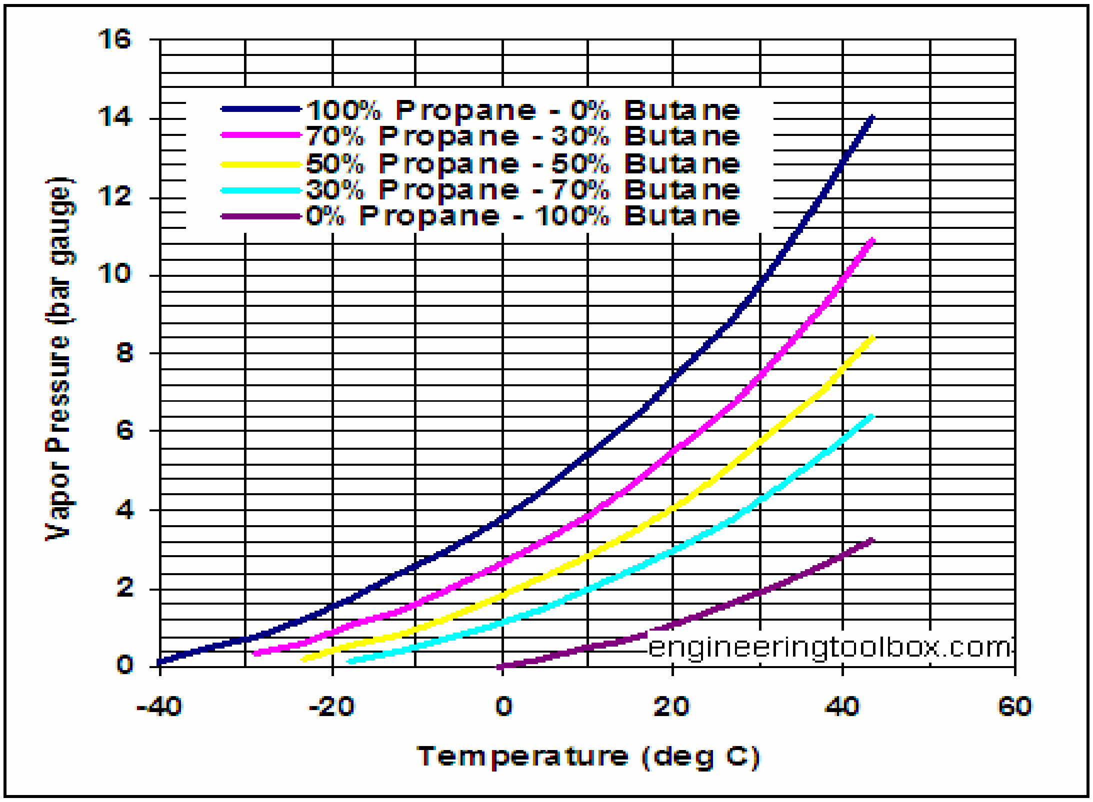

Figure 2.2: Propane Butane Mixture Vapor Diagram – bar

2.3 Synthesis of LPG

There are three methods for synthesis of LPG. First, LPG is synthesis from syngas. The second method is indirect synthesis of LPG from syngas, synthesis of methanol or dimethyl ether (DME) from syngas, conversion of methanol or DME into hydrocarbon of LPG fraction (olefin and paraffin), and then olefin hydrogenation to LPG. And the last method is semi indirect synthesis of LPG from syngas, synthesis of DME from syngas or methanol and conversion of DME into LPG in presence of hydrogen [1].

2.4 LPG Usage

When LPG is used to fuel internal combustion engines, it is often referred to as autogas. In some countries, it has been used since the 1940s as an alternative fuel for spark ignition engines. More recently, it has also been used in diesel engines [1]. In highly purified form, various blends of the LPG constituents propane and iso-butane are used to make hydrocarbon refrigerants, which are increasingly being used in refrigeration and air conditioning systems including domestic refrigerators, building air conditioners and vehicle air conditioning. This is partly because of concerns about the ozone depleting and greenhouse effects of the widely used HFC 134a. Hydrocarbons are more energy efficient, run at the same or lower pressure and are generally cheaper than HFC 134a [4].

2.5 Calorific Value

The calorific value of a fuel is the quantity of heat produced by its combustion at constant pressure and under a conditions known as normal of temperature and pressure (to 0^oC and under a pressure of 1,013 mbar) [6]. The combustion of a fuel product generates water vapor. Certain techniques are used to recover the quantity of heat contained in this water vapor by condensing it.

The higher heating value (HHV, also known gross calorific value or gross energy) of a fuel is defined as the amount of heat released by a specified quantity (initially at 25°C) once it is combusted and the products have returned to a temperature of 25°C. The higher heating value takes into account the latent heat of vaporization of water in the combustion products, and is useful in calculating heating values for fuels where condensation of the reaction products is practical (example in a gas-fired boiler used for space heat) [6].

The lower heating value (also known as net calorific value or LHV) of a fuel is defined as the amount of heat released by combusting a specified quantity (initially at 25 °C or another reference state) and returning the temperature of the combustion products to 150 °C. The lower heating value assumes the latent heat of vaporization of water in the fuel and the reaction products is not recovered. It is useful in comparing fuels where condensation of the combustion products is impractical, or heat at a temperature below 150 °C cannot be put to use [6].

Below is the table of calorific value of the existing fuel and common material today [6].

Table 2.0: Value CV of the existing fuel and common material

Material		Gross Calorific Value (Btu/lb)
Carbon	C	14,093
Hydrogen	H_2	61,095
Carbon Monoxide	CO	4,347
Methane	CH_4	23,875
Ethane	C_2H_4	22,323
Propane	C_3H_8	21,669
n-Butane	C_4H_{10}	21,321
Isobutane	C_4H_{10}	21,271
n-Pentane	C_5H_{12}	21,095
Isopentane	C_5H_{12}	21,047
Neopentane	C_5H_{12}	20,978
n-Hexane	C_6H_{14}	20,966
Ethylene	C_2H_4	21,636
Propylene	C_3H_6	21,048
n-Butene	C_4H_8	20,854

2.6 Flame Stability

There are several well-defined areas of operation for a burner that operates on gaseous fuels. The three regimes may be distinguished as follows, first is yellow tipping. When the airflow to burner is prevented, the flame will have a yellow tip and may produce smoke. When the airflow is increased, yellow tip disappears and is replaced by a blue non-luminous flame. Second is lift off. When the airflow to burner is gradually increased with a constant gas flow, if sufficient gas flow exists, the yellow tipping will disappear and blue flame will be established. Further increase in airflow will result in the lifting of the flame around the surface of the burner. At this moment, the velocity of mixture leaving the burner approaches the mixture flame speed. If airflow is further increased, the flow velocity will exceed the flame speed and the flame will lift off and be extinguished. The last is light back. With a low burner loading, when the airflow is increased, after observing yellow tipping and blue flame, flame will move down the tube to inlet part which means that flame speed exceeds the flow velocity [3].

2.7 Flue Gas

Flue gas is gas that exits to the atmosphere via a flue, which is a pipe or channel for conveying exhaust gases from a fireplace, oven, furnace, boiler or steam generator. Quite often, it refers to the combustion exhaust gas produced at power plants. Its composition depends on what is being burned, but it will usually consist of mostly nitrogen (typically more than two-thirds) derived from the combustion air, carbon dioxide (CO_2) and water vapor as well as excess oxygen (also derived from the combustion air). It further contains a small percentage of pollutants such as particulate matter, carbon monoxide, nitrogen oxides and sulfur oxides [7]. The environmental emission of Carbon Dioxide from the combustion of different fuels can be approximated from the table below [6]:

Table 3: Environmental emission of Carbon Dioxide from combustion of different fuel

Fuel	Emission of CO_2 (kg/kWh)
Coal	0.34
Light Oil	0.28
Natural Gas	0.20
Methane	0.20
LPG – Liquid Petroleum Gas	0.20
Bioenergy	0

2.8 Combustion and Exhaust Emission Characteristics of a using LPG-Diesel Blended Fuel

Currently, various alternative fuels have been investigated for Diesel engines to reduce the consumption of Diesel fuel and the nitrogen oxide (NOx) and particulate emissions. Liquefied petroleum gas (LPG) and compressed natural gas (CNG) are most widely used as a fuel for spark ignition (SI) engines because of their low octane number. Over the European Test Cycle at 25 0C, an LPG operated vehicle provided a substantial benefit of reduced emissions compared to those of unleaded gasoline. Hydrocarbon (HC) emissions were reported as 40% lower, carbon monoxide (CO) as 60% lower and carbon dioxide (CO2) as substantially reduced, principally due to the high hydrogen/carbon ratio of LPG when compared to gasoline. A higher thermal efficiency and, therefore, improved fuel economy can be obtained from internal combustion engines running on LPG as opposed to unleaded gasoline. This is because LPG has a higher octane number, typically 112 research octane number (RON) for pure propane, which prevents the occurrence of detonation at high engine compression ratio. In dual fuel engines under low loads, when the LPG concentration is lower, the ignition delay of the pilot fuel increases and some of the homogeneously dispersed LPG remains unburned, resulting in poor emission performance. Poor combustion of LPG under low loads because of a dilute LPG–air mixture results in high CO and unburned HC emissions. However, at high loads, increased admission of LPG can result in uncontrolled reaction rates near the pilot fuel spray and lead to knock [2].

2.9 Flame Stability and Emission characteristics of simple LPG Jet diffusion Flame

Stability of a turbulent jet diffusion flame has received renewed attention in recent years due to its varied practical applications in diffusion flame based combustors. At higher fuel flow rate, the diffusion flame has a tendency to get lifted off from the burner rim. The lifted diffusion flame is unstable and can blow-off or extinguish at any time when the lift-off height increases beyond certain critical height. Thus flame stability of the lifted diffusion flame is an important parameter for basic combustor design. Investigation for stability characteristics of lifted methane jet diffusion flames in terms of lift-off height, HL and found that the fuel and air are fully premixed at the base of a lifted diffusion flame. It presumed that the flame gets stabilized at the position where the mean flow velocity is equal to the burning velocity of a stoichiometric premixed turbulent flame. The time averaged temperature, concentration and velocity measurements at positions around the stabilization region of the lifted flames [3].