The Effect of Iraqi Liquefied Petroleum Gas (LPG) Addition to a Liquid Hydrocarbon Fuels on Emission of an Industrial Furnace Burner

Abdul AL-Kadhim M Hasan Hadi
Mechanical Engineering Department
University of Technology-Baghdad.
akmh1@yahoo.com

Sardar Othman Qadir
Mechanical Engineering Department
University of Technology-Baghdad.

Abstract

The emission sources have great effects on our environment. Further using of fossil fuels because of our needs for heating purposes and developments leads to raising the emission concentration in the air which caused to health risks to human society and its environment. This paper deals with using a different percentage of Iraqi liquefied petroleum gas from 10% to 25% with different percentage of Iraqi Gas-oil fuel from 90% to 75%, keeping the thermal load constant in order to indicate the possibility of reducing the pollutant emissions . A dual fuel burner and equivalence ratio range from 0.8 to 1.4 is used to study the emission concentrations based on these equivalence ratio. For further reducing in emission and heat recovery from the exhaust gases the cooling effect also investigated for water mass flow-rate from 12 kg/s to 48 kg/s roughly. The results showed that for further increasing equivalence ratio the UHC, CO, and Soot increased by about 3% and NO_x, and CO_2 decreased by 2.5% and this due to decreasing the oxygen ratio in the mixture and incomplete combustion occurred. Also for increasing percentage participating of LPG fuel as a secondary fuel, UHC, CO, and Soot decreased by 8%and NO_x and CO_2 increased slightly. With heat recovery process the concentration of UHC, CO, and Soot increased slightly while NO_x, CO_2 decreased by 1.5% because of decreasing of combustion chamber temperature.

Keywords: continuous combustion emissions, Liquefied petroleum gas.

1-Introduction

External combustion engines are widely used in numerous applications throughout the world in domestic heating purposes or industrial furnaces, and boilers. A dual fuel burners is a new type of burners using more than one kind of fuels in order to depends on alternative fuels when there is a shortage in local markets of one of them and this represents energy management opportunity which leads to saving in expensive primary fuels such as Gas-oil and LPG[**1,2**]. Much works have been done to reduce the production of NO_x, CO, UHC, and photochemical smog in order to match the requirements of friendly environmental **[3, 4]**. Joanne M. Smedley and Alan Williams **[5]** explored the most important reason behind adding gaseous fuel and that the tests showed that dual fuel emissions are substantially lower in soot and particulate matter than petroleum diesel emissions. Al Omari et .al **[7]** studied the effect of using dual fuel on the performance of small dual fuel furnace. They found that adding gaseous fuel leads to improve the whole performance of the furnace. Zahmatkesh and M. Moghiman**[8]** concluded that the reduction of droplet size leads to reduction in soot. The present work investigates the effect of adding liquefied petroleum gas to gas oil fuel on the emissions of a locally fabricated industrial burner. The burner will be examined under various operational conditions in order to promote design and specify the best mixing proportion of liquefied petroleum gas with hydrocarbon fuels. Also the effect of exhaust cooling gases on emission concentration were investigated as a heat recovery from the stacks, the work considered five thermal load to investigate for emission, and to be applicable in industrial and domestic use with certain percentage of Gas-oil and LPG.

2- Experimental work

A detail description of the test rig used in this work and the experimental work is summarized below:

The test rig that is completely constructed and used in this study is shown in Figure 1. The liquid fuel is stored in a fuel tank and forced in fuel injection system by compressed air produced by a reciprocating compressor. The compressed air is also used to atomize the liquid fuel in order to generate very small size droplets. The LPG fuel is supplied from a domestic LPG cylinder and Gas-oil supplied from a storage tank.

The different LPG percentage addition which select according to the thermal load choosed is controlled by LPG volume flow-rate flowmeter, and the mass flow-rate of Gas- oil is controlled by a Rota-meter which provides the rest of the thermal load to obtain certain thermal load by the LPG and Gas-oil fuels together and the air mass flow-rate is controlled by a shutter with orifice. The emission concentration is measured by gas analyzer for UHC, CO, CO_2, and NOx, and the evaluation was done for Soot by smoke meter.

Figure (1) shows the dual fuel burner, Figure (2) shows the schematic diagram of the test rig and its parts, and Figure 3 shows the emission detecting devices gas analyser and smoke meter.

Specification of the fuels used in the present work is explained in Table 1 which is provided by (Al Dora refinery).

Table (1): Specification of fuel used.

No	Fuel	Equivalent Chemical formula	Density (ρ) kg/m^3	Surface tension (σ) kg/s^2	H/C ratio	A/F ratio	Calorific value
1	Gas oil	$C_{9.12}H_{16.85}$	840	0.0267	1.84	14.5/1	43000 kJ/kg
2	LPG	$C_{3.34}H_{8.68}$	1.98	-	2.59	15.5/1	111983.52 kJ/m^3

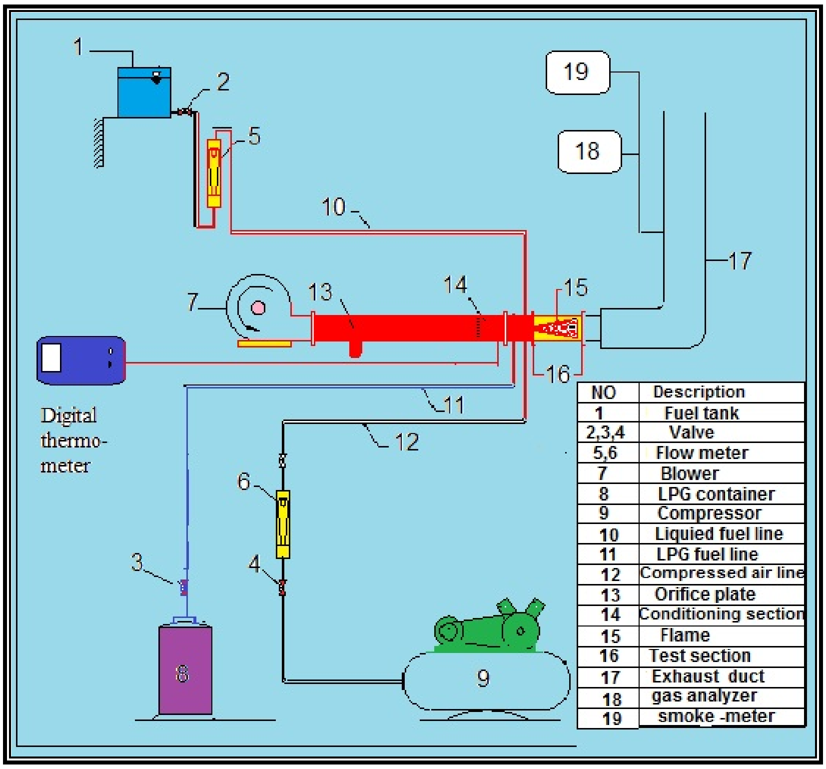

Figure 1: The test rig.

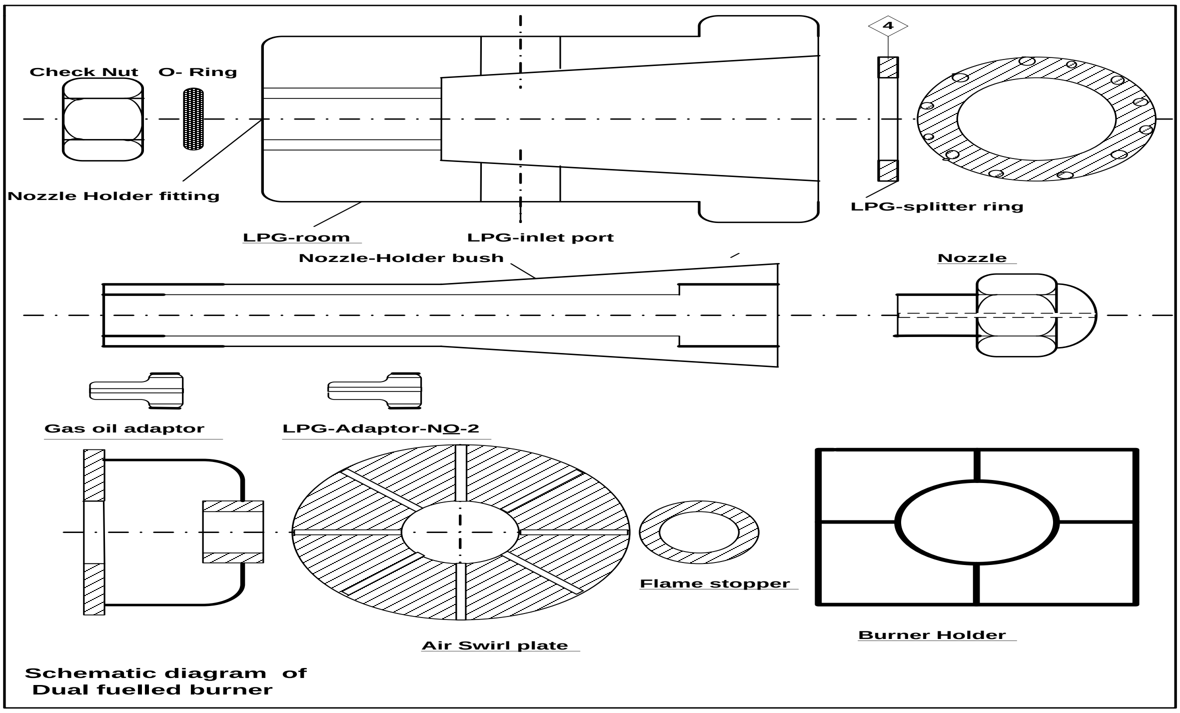

Figure 2: Schematic diagram of the dual fuel burner.

(a) (b)

Figure 3: Emission detecting devices (a) Gas analyser (b) Smoke meter

3-Results and discussion:

Different runs were chosen with five thermal loads, the first run was done by changing the equivalence ratio for each thermal load with combusting Gas-oil fuel only, the results shown in Figures 4to6 indicate that with increasing the equivalence ratio from (0.6-1.4) the emission concentrations begins to increase for UHC, CO, and Soot and this due to incomplete combustion in agreement with [5, 8], while Figures 7 and 8 showed that NO_x, CO_2 is decreased with increasing the equivalence ratio from (0.6-1.4) and this due to decreasing temperature and oxygen content of the mixture which agreed with [3, 4].

It also noticed that with increasing thermal loads value the rate of emission concentration of UHC increased as can be shown in Figure 9, and this thought due some of high contents of volatile hydrocarbons in gaseous fuel escape out of combustion zone and don’t take part in combustion. Figures 10 and 12 shows that concentration of CO and soot are decreased in the addition of LPG in ranges from 0 to 20 percent due to improvement in combustion caused by the increasing of pressure jet atomizer which mean the gas-oil mass flow-rate is directly proportional with atomizing pressure and this will reduce the droplet size diameter, and gives more efficient evaporation of the fine droplets and decreasing the residence time and more homogeneous mixture [6].

Adding LPG fuel to the mixture caused the emissions concentration of NO_x, and CO_2 to increased as shown in Figures 11and 13 because of increasing the flame temperature and accelerating the fuel droplet evaporation [7].

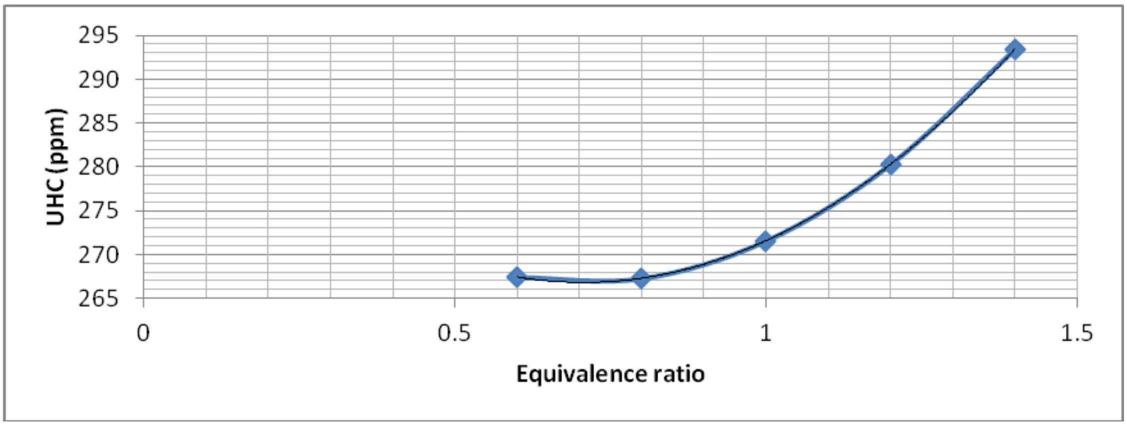

Figure 4: Thermal load (29.7 kW)

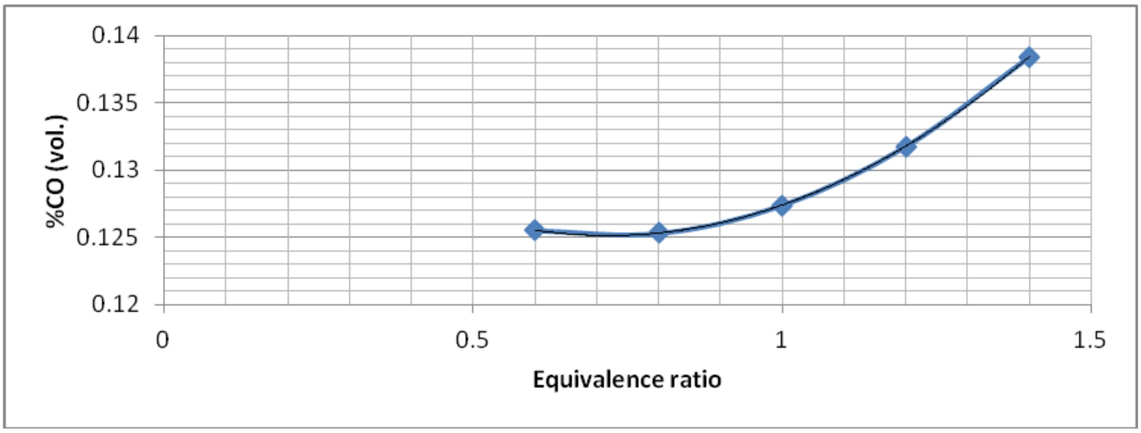

Figure 5: Thermal load (29.7 kW)

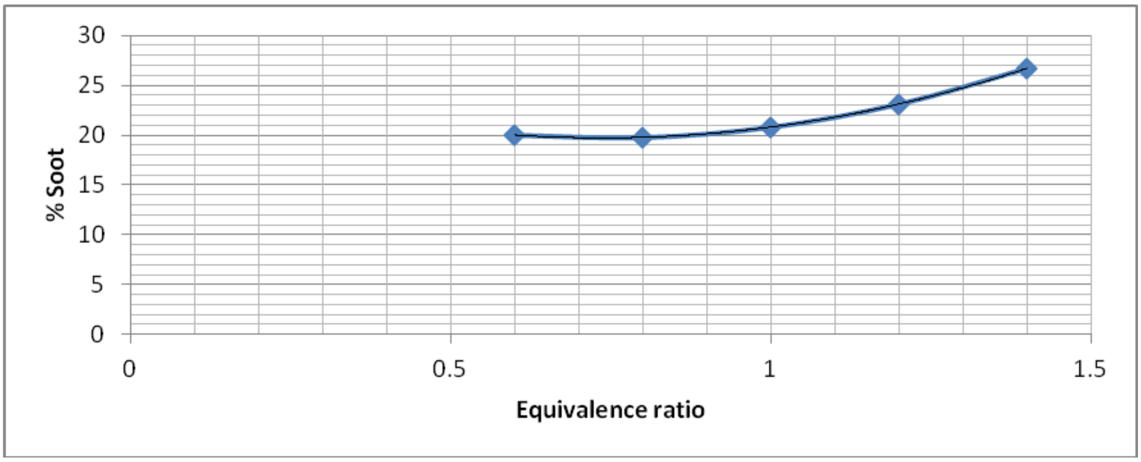

Figure 6: Thermal load (29.7 kW)

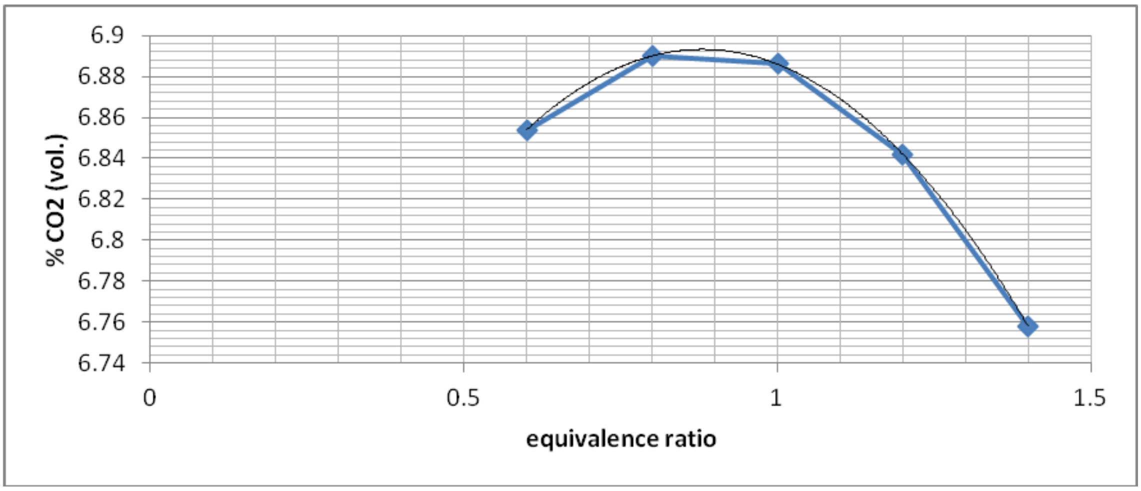

Figure 7: Thermal load (29.7 kW)

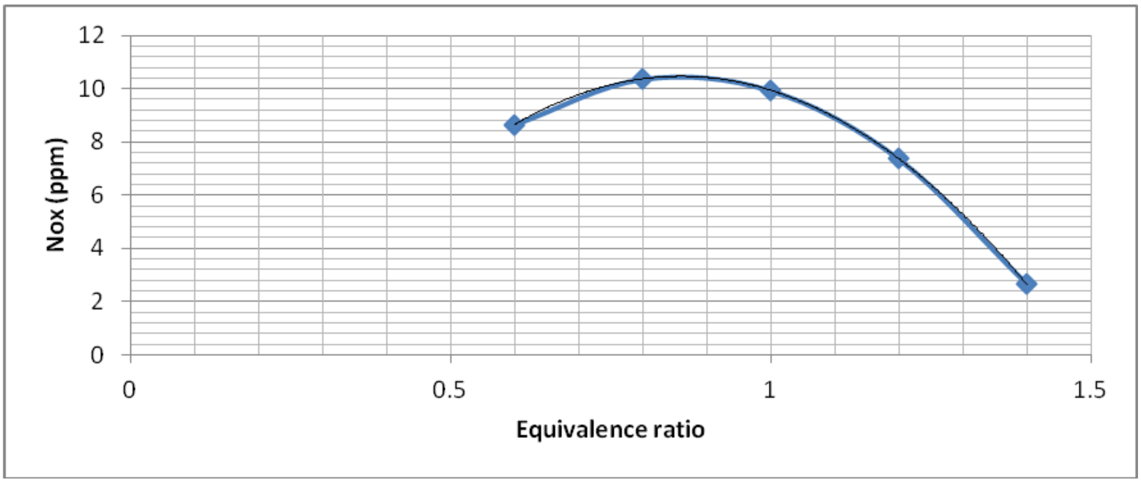

Figure 8: Thermal load (29.7 kW)

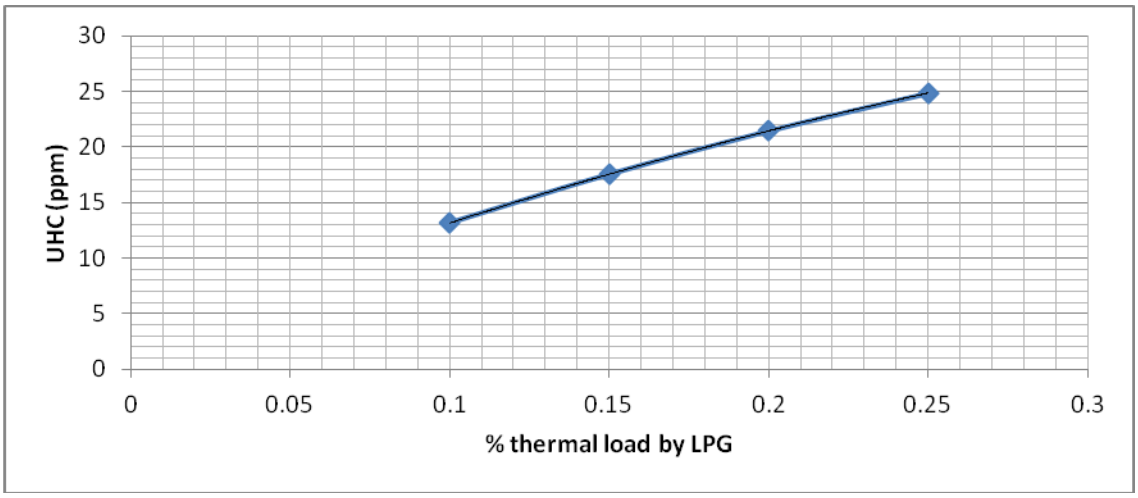

Figure 9: Thermal load (29.7 kW) φ=0.8

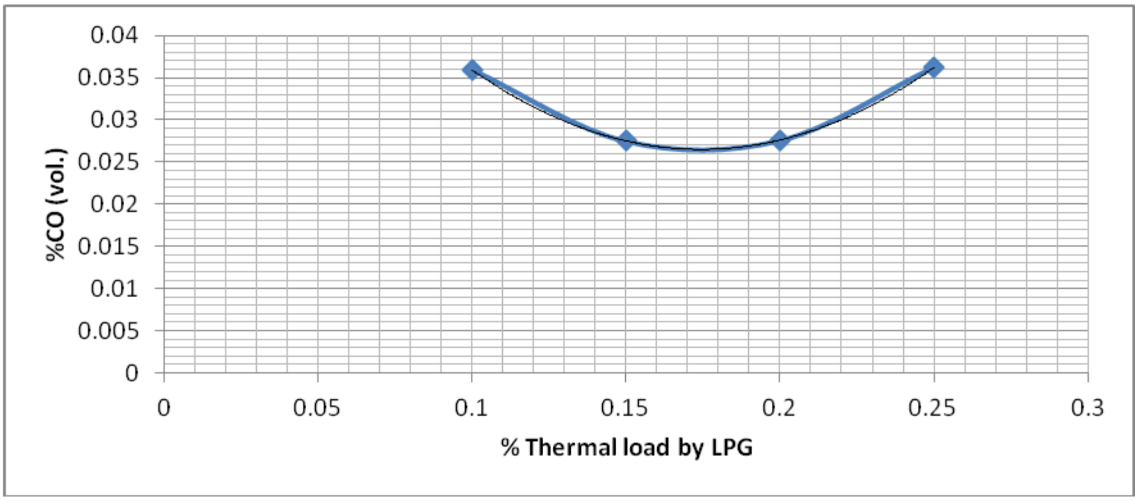

Figure 10: Thermal load (29.7 kW) φ=0.8

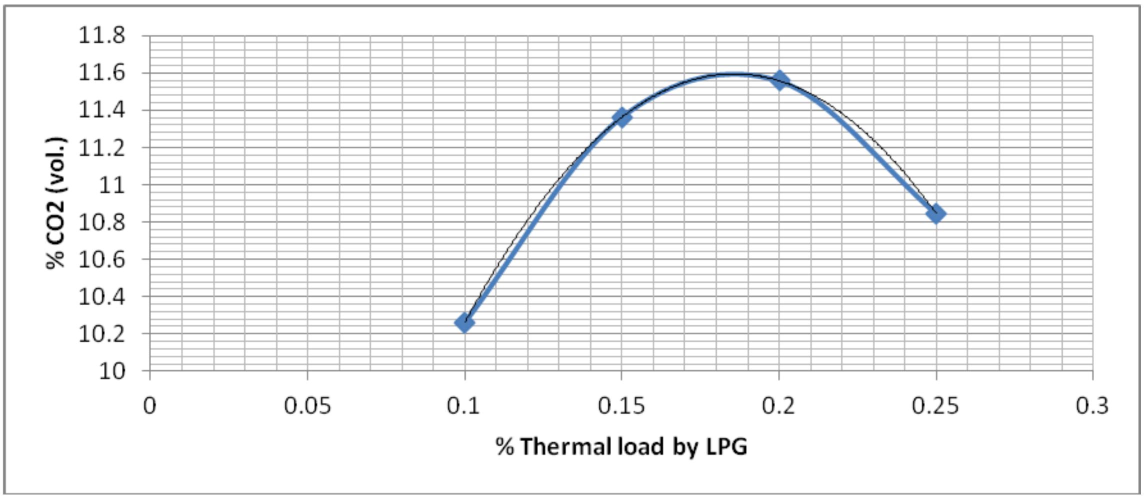

Figure 11: Thermal load (29.7 kW) φ=0.8

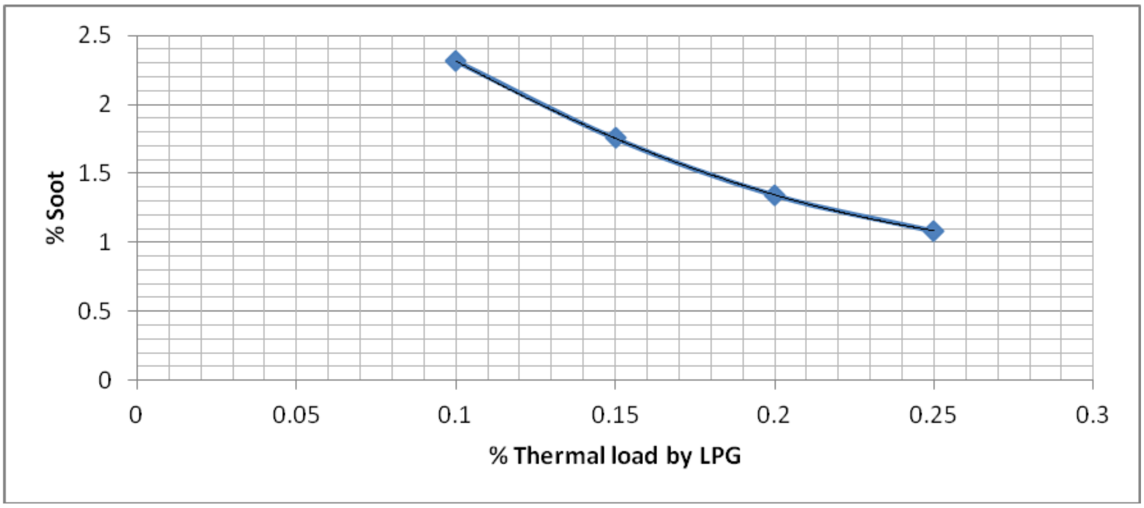

Figure 12: Thermal load (29.7 kW) φ=0.8

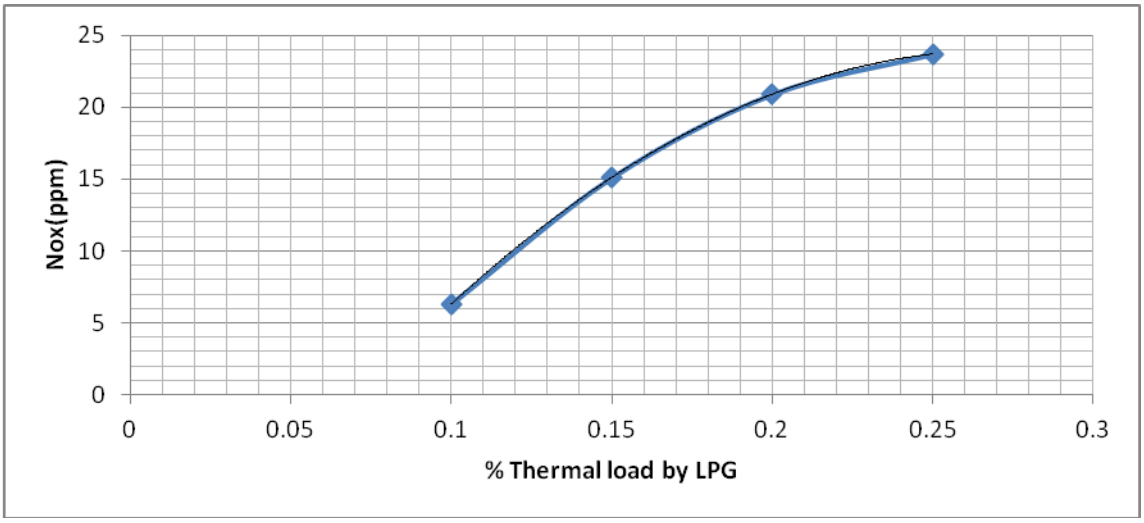

Figure 13: Thermal load (29.7 kW) φ=0.8

4-Conclusion:

From the obtained results we conclude the following for all thermal loads.

1- The increasing of the equivalence ratio leads to improvement in combustion and as a result the concentrations of UHC, CO, and soot decreased while the NO_x, and CO_2 increased.

2- Decreasing of droplet size leads to decrease all pollutants.

3- Further decreasing of UHC, CO, and Soot noticed with adding LPG as a secondary fuel, while increases in NO_x, and CO_2 observed with increased percentage of LPG.

References:

1-“ **Effect of Fuel-Air-Ratio Nonuniformity on Emissions of nitrogen oxides**” by Valerie J. Lyons, NasaTechnical Paper 1798,November 1981.

2- Rohschild, W.G, E.W. Kaisera, G.A. Rohschilda and L. Lavoa ,"**Effects of fuel-air equivalence ratio, temperature, and inhibitor on the structure of laminar methane-air flames**", Research Staff. Ford, Motor Company. P.O. box 2053, Dearborn, Michlgan 4812 1, USA Combust. Sri. And Tech. Vol. 47. pp. 209-227,1986.

3- K.K. Rink and A.H.Levebaver ," **The influence of fuel composition and spray characteristic on nitric oxides formation**" Gas Turbine Combustion Laboratory , Thermal Sciences and Propulsion Center School of Mechanical Engineering ,West Lafayette, IN 47907, Combust. Sci. and Tech, Vol. 68, pp. 1-14 ,U.S.A,1989.

4- Edgar P. Paz , Joao A. Carvalho Jr. , Luiz R. Carrocci1, Ely V. Cortez , and Marco A. Ferreira ," **Comparative Study between Diesel Fuel and Hydrated Ethanol in Direct Burning** ", Department of Energy, Sao Paulo State University, Campus of Guaratingueta.

5- Joanne M. Smedley and Alan Williams, **" Soot deposition from ethylene air flame and the role of aromatic intermediates**", Department of Fuel and Energy, Leeds University, Leeds, LS2 9JT, UK. 1990

6- Amer Mahdi Ghasemi, Mohammad Moghiman, SeyedMohamajavadi , and Naseh Hosseini, "**Effect of Droplet Size and Air Preheating on Soot Formation on Turbulent Combustion of Liquid Fuel**" Paper No ESDA 2010-2433,PP.211-217;7Pages,doi:10.1115/ESDA 2010-24633.

7-Al Omari, S.-A. B. and B. Abu-Jdayil, “**Some considerations of the performance of small dual fuel furnaces fueled with a gaseous fuel and a liquid fuel mix containing used engine lube oil**”. Renewable Energy 56: 117-122 October-2012.

8- Zahmatkesh and M. Moghiman, "**Effect of liquid fuel droplet size on soot emission from turbulent spray flames** ", Iranian Journal of Science & Technology, vol. 30, pp.339-351, No. B3, Faculty of Mechanical Engineering, Ferdowsi University of Mashhad, 2006

تأثير إضافة غاز البترول المسال العراقي الى وقود هيدروكربوني سائل على انبعاث موقد فرن صناعي

عبد الكاظم محمد حسن هادي
قسم الهندسة الميكانيكية
الجامعة التكنولوجية

سردار عثمان قادر
قسم الهندسة الميكانيكية
الجامعة التكنولوجية

الخلاصه

ان مصادر التلوث لها تاثير كبير على البيئه وان استخدام المزيد من الوقود الاحفوري بسبب حاجتنا اليه لاغراض التسخين والتطورات الحاصله في هذا المجال ادت الى رفع مستوى تراكيز الملوثات في الهواء والتي بدورها اثرت سلبا على البيئه و على الصحه العامه للانسان

تتناول هذه الدراسه اضافة تراكيز مختلفه من الغاز النفطي المسال العراقي الى زيت الغاز العراقي السائل لبيان امكانية عمله على تقليل الملوثات المنبعثه من احتراق الوقود الهيدروكربوني السائل . تراوحت نسب الاضافه بين 10% الى 25% مع المحافظه على بقاء الاحمال الحراريه ثابته. ولغرض قياس تراكيز الملوثات المنبعثه فقد تم استخدام محرق مزدوج الوقود وتم اجراء التجارب بتغيير النسبه المكافئه من 0.8 الى 1.4. كذلك ولغرض احداث تقليل اضافي في نسب هذه التراكيز فقد تم اللجوء الى تبريد الغازات العادمه عن طريق مبادل حراري تراوح معدل جريان الماء فيه من 12 كغم/ثانيه الى 48 كغم \ ثانيه.

اظهرت النتائج بان زيادة النسبه المكافئه تؤدي الى زيادة تراكيز الهيدروكربونات غير المحترقه, اول اوكسيد الكربون, والسخام بينما تؤدي الى تناقص كل من اكاسيد النيتروجين و ثاني اوكسيد الكربون. وهذا يعزى الى تناقص الاوكسجين المتاح في الخليط وبالتالي عدم حصول الاحتراق التام.كذلك اظهرت النتائج بان زيادة نسبة اضافة الغاز النفطي المسال الى الوقود السائل المستخدم تؤدي الى تقليل تراكيز الهيدروكربونات غير المحترقه, اول اوكسيد الكربون, والسخام وزيادة تراكيز كل من اكاسيد النيتروجين و ثاني اوكسيد الكربون. اما في حالة تبريد الملوثات الناتجه فان النتائج اظهرت زياده في تراكيز الهيدروكربونات غير المحترقه, اول اوكسيد الكربون, والسخام و نقصان في تراكيز كل من اكاسيد النيتروجين و ثاني اوكسيد الكربون ويمكن ان يعزى ذلك الى تناقص درجة حرارة غرفة الاحتراق..

كلمات داله: ملوثات الاحتراق المستمر و الغاز النفطي المسال