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

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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 NOx, and CO2 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 NOx, and CO2 increased slightly. With heat recovery process the concentration of UHC, CO, and Soot increased slightly while NOx, CO2 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 NOx, 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, CO₂, 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 analyzer 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

<table>
<thead>
<tr>
<th>No</th>
<th>Fuel</th>
<th>Equivalent Chemical formula</th>
<th>Density (ρ) kg/m³</th>
<th>Surface tension (σ) kg/s²</th>
<th>H/C ratio</th>
<th>A/F ratio</th>
<th>Calorific value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Gas oil</td>
<td>C₉H₁₂</td>
<td>840</td>
<td>0.0267</td>
<td>1.84</td>
<td>14.5/1</td>
<td>43000 kJ/kg</td>
</tr>
<tr>
<td>2</td>
<td>LPG</td>
<td>C₃H₈</td>
<td>1.98</td>
<td>-</td>
<td>2.59</td>
<td>15.5/1</td>
<td>111983.52 kJ/m³</td>
</tr>
</tbody>
</table>

Figure 1: The test rig.
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 4 to 6 indicate that with increasing the equivalence ratio from (0.6-1.4) the emission concentrations begins to increase for UH.C, CO, and Soot and this due to incomplete combustion in agreement with [5, 8], while Figures 7 and 8 showed that NOx, CO2 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 NOx, and CO2 to increased as shown in Figures 11 and 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) $\varphi=0.8$
Figure 10: Thermal load (29.7 kW) $\phi=0.8$

Figure 11: Thermal load (29.7 kW) $\phi=0.8$

Figure 12: Thermal load (29.7 kW) $\phi=0.8$
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 NOx, and CO2 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 NOx, and CO2 observed with increased percentage of LPG.

References:

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
تأثير إضافة غاز البترول المسال العراقي إلى وقود هيدروكربوني سائل على انبعاث موقود فرن صناعي

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الخلاصة

أن مصدر التنويم للاس تأثير كبير على البيئة. وان استخدام المزيد من الوقود الاحترافي بسبب حاجتنا الى توفير التسخين والمروج والتطورات الحالية في هذا المجال ادت الى انتاج مستويات تراكم الانواع في الهواء والتي تديرها تدريجاً على البيئة. وان الصبح العلماء للانسان تتناول هذه الدراسه اضافات تراكم مختلطة من الغاز النفطي السائل العراقي إلى زيت الغاز العراقي السائل لبيان امكانية عمله على تقليل انواع المنبعثة من احتراق الوقود الهيدروكربوني السائل. تراوح نسب الإضافات بين 10% الى 25% مع المحافظة على بقاء الاحمال الحرارية ثابتة. وتعرض تقييم تراكم الانواع المنبعثة فقد تم استخدام محرق مزدوج الوقود وتجربة التجربة بتغيير النسبة المكافئة من 0.8 إلى 1.4. وكذلك تعرض احداث تقليل اضافي في نسبة هذه الزيادات. قد تم اللجوء إلى تبريده الغازات العامل عن طريق ملء حارية تراوح معدل جرير الماء في 12 كم/ثانية إلى 48 كم/ثانية.

لاحظت النتائج ان زيادة النسبة المكافئة تؤدى الى زيادة تراكم الهيدروكربونات غير المحترقة. اول اوكسيد الكربون. والشحم بينما تؤدي إلى تناقص كل من اكسيد النيتروجين و ثاني اوكسيد الكربون. وهذا يعزى إلى تناقص الأوكسجين الناجح في الخليط وبالتالي عدم حصول الاحتراق. كذلك اظهرت النتائج ان زيادة نسبة إضافات الغاز النفطي السائل لزيادة ثبات الزيادات المنبعثة إلى تقليل تراكم الهيدروكربونات غير المحترقة. اول اوكسيد الكربون. والشحم وزيادة تراكم كل من اكسيد النيتروجين و ثاني اوكسيد الكربون. أما في حالة تبريده الغازات الناتجة فإن النتائج اظهرت زيادة في تراكم الهيدروكربونات غير المحترقة. اول اوكسيد الكربون. والشحم ونقص في تراكم كل من اكسيد النيتروجين و ثاني اوكسيد الكربون. ويمكن ان يعزى ذلك الى تناقص درجة حرارة غرفة الاحتراق.

كلمات دالة: انواع الاحتراق المستمر و الغاز النفطي السائل