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Study of Liquefied Petroleum Gas Heating Value
A Thermodynamics Approach

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Abstract – The heating value of liquefied petroleum gas (LPG) is an important characteristic implying LPG fuel-quality. Nevertheless, the quantitative and detail study on the heating value of LPG is still in high scarcity. Hence, the heating value of LPG is analyzed extensively in the present study. A combustion reactor simulated employing Aspen-Hysys simulator is used to determine the heating value. The separate effects of the presences of additives or foreign components (e.g., ethane, hydrogen sulfide, moisture, and mercaptan), the proportion of primary LPG components (e.g., propane and butane), and the combustion temperature and pressure on the heating value of LPG are studied. Explanations of the observed effects are also provided. The present study would help the researchers, manufacturers, bottlers, and distributors of LPG immensely.

Keywords –Heating value; LPG; Aspen-Hysys process simulator; Fuel.

1. Introduction

On the basis of reserve and uses, natural gas is the main energy resource in Bangladesh. Since it is being used in the sectors of power, industrial, commercial, domestic, automobile, etc largely, the reserve of natural gas is depleting rapidly. As exploration of new gas fields in Bangladesh is not going as expected, it will not be possible for natural gas to fulfill the demand solely after a decade [1]. From this scenario the necessity of energy-diversification is felt. Liquefied petroleum gas, LPG is a mixture primarily of propane and butane. It has already been proved as an efficient alternative domestic fuel in Bangladesh. It can also used as a fuel in heating appliances and vehicles. To popularize and enhance the uses of LPG also require fundamentals research at various aspects. Heating value is a very important character of any combustion-fuel indicating the fuel quality or value. It is expected that the heating value of LPG is affected by the parameters like presences of additives or foreign components, proportion of primary LPG components, and combustion pressure and temperature, etc. Unfortunately, no quantitative and detail study on the effect of the important parameters stated above on the heating value of LPG is available in the literature. Therefore, the objective of the present study is to the study of the separate effects of the presences of additives or foreign components (e.g., ethane, hydrogen sulfide, moisture, and mercaptan) in LPG, the proportion of primary LPG components (e.g., propane and butane), and the LPG combustion temperature and pressure. The Aspen-HYSYS process simulator is used in this study to determine the heating value at various conditions.

2. Methodology

Heating value is normally defined as the amount of heat obtained from the complete combustion of one unit of fuel (e.g., LPG). The pure experimental setup to determine this heating value especially for LPG is rarely available. Hence the simulation method is adopted to determine the heating value. A combustion reactor is created in AspenHYSYS 7.1 process simulator as shown in Fig.1. The simulation and heating value determination are briefly stated below:

A new file in Aspen-HYSYS is opened and a package unit (e.g., SI unit) is chosen from preference tab. The various components (e. g. ethane, propane, butane, mercaptan, hydrogen sulfide, water, methanol, ethanol, oxygen, and nitrogen, etc.) are selected from the component tab. Subsequently, an appropriate fluid package (i.e., Peng Robinson) is selected from the fluid package tab. The specific reactions are also defined in the reaction tab and the selected fluid package is assigned to each reaction. After entering into the simulation environment the reactor (i.e., conversion type) is taken from object pellet. A 100 % conversion of each LPG component is added to the reactor as a parameter. Then the LPG and air streams at a given condition are finally added to the reactor [2]. An energy stream (E, in Fig. 1) is also added to the reactor to represent the heat generated by the combustion reactions. With the run

of the simulation, the reactions are completed and the heating value is obtained from the energy stream, E.

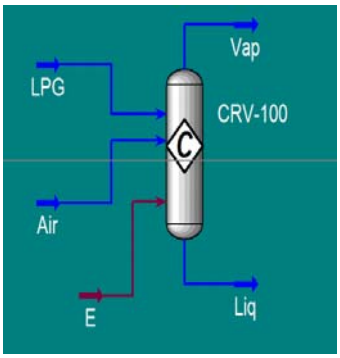

Figure1. Combustion reactor and associated streams in Aspen HYSYS simulator

3. Results and Discussion

The effects of various parameters on the heating value of LPG are presented and discussed in the following sub-sections.

3.1. Effect of additives or foreign components

During the manufacture of LPG, ethane can come into it. Similarly, H_2S and moisture can also be present in LPG. In addition, mercaptan is deliberately added to commercial grade LPG to identify the leakage of LPG from cylinder or bottle. Therefore, it is required to know the effect of these additives or foreign components on the heating value of LPG. Fig. 2 clearly shows that the heating value decreases monotonically if the proportion of ethane increases. This is because the heating value of ethane is lower than that of LPG primary components (i.e., propane and butane). Fig. 3 also indicates that the heating value decreases monotonically with the increases in the proportion of H_2S in LPG. This also happen due to the fact that the heating value of H_2S is much lower than that of propane and butane. Finally, Figs. 4 and 5 also show the same effect that is the heating value of LPG decreases with the increases in the proportions of moisture and mercaptan [3]. In addition, here the decreasing effect is severe than that of ethane and H_2S. This is because both the moisture and mercaptan are non-combustible. Therefore, it is desirable to suppress the proportions of additives or foreign components in LPG as much as possible.

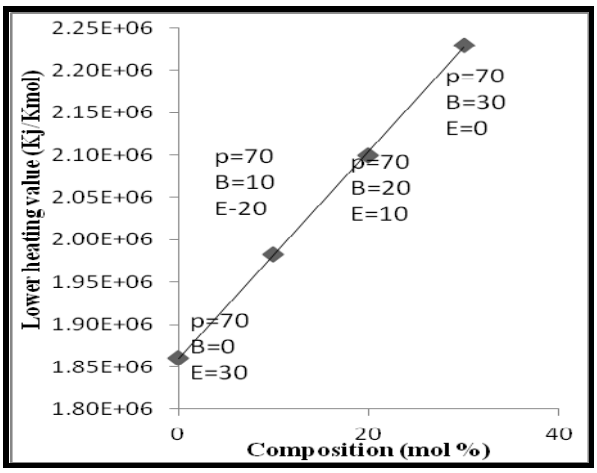

Figure2. Effect of ethane on the heating value of LPG

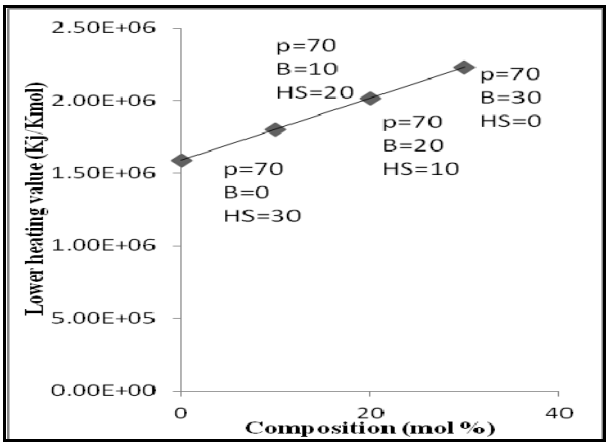

Figure3. Effect of hydrogen sulphide on the heating value of LPG

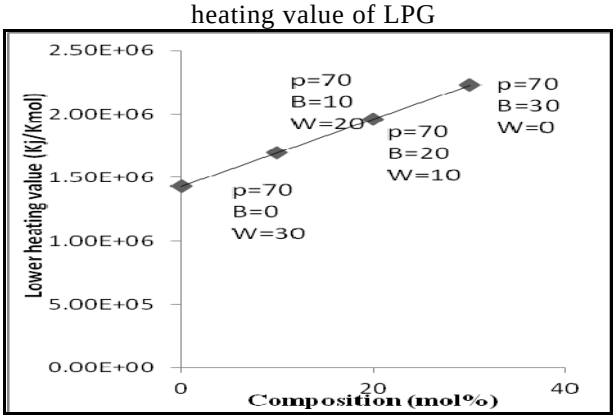

Figure4. Effect of hydrogen sulphide on the heating value of LPG

3.2. Effect of Primary Component

The propane and butane are the primary components of LPG. Fig. 6 shows that with the increase in the proportion of propane, the heating value per unit volume of LPG also decreases substantially. This is because the heating value of pure propane is lower than that of pure butane in volume basis units. The actual reason behind the lower heating value of propane is that, in a unit volume, propane has the lower number of carbon atom (C) than butane, which are converted into C-O bond upon combustion generating lower amount of heat than butane [4]. Same qualitative trend is observed if the heating value is considered per unit mole and mass of LPG. Hence, it is

desirable to have more butane in LPG to yield higher heating value of the mixture.

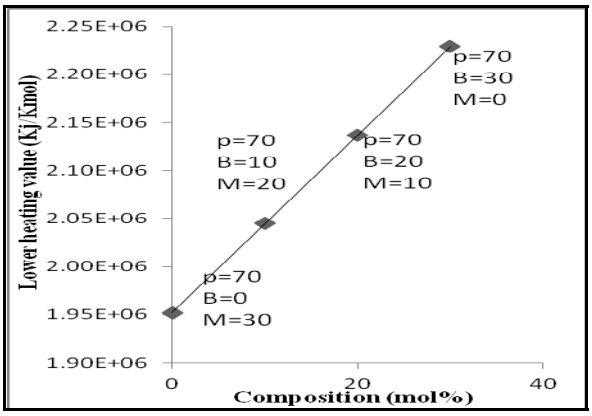

Figure5. Effect of mercaptan (M) on the heating value of LPG

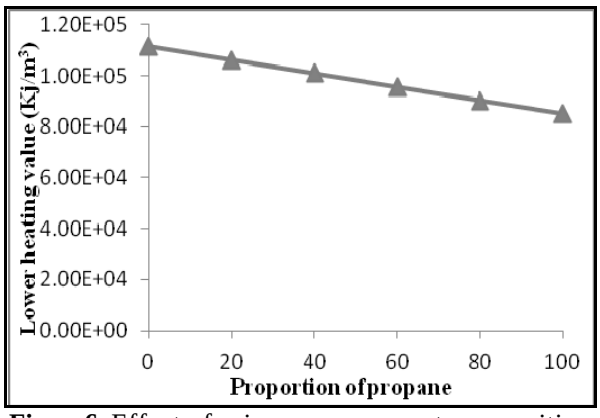

Figure6. Effect of primary component composition

3.3. Effect of combustion temperature and pressure

Having the same pressure different geographical regions utilizing LPG as cooking and heating fuel can be at different temperatures. Similarly, having the same temperature the geographical regions can hypothetically be under different pressures too. In addition, numerous industrial and mechanical units employing LPG as a combustion fuel can be under different temperatures and pressures. Therefore, LPG with a particular quality can give different heating values upon combustion at different temperatures and pressures. As a result, it is also very important to know the effect of combustion temperature and pressure on the heating value of LPG [5].

The effect of combustion temperature on heating value is studied over a temperature range of -50 to 200°C under three separate pressures of 1, 5, and 10 atm. Fig. 7 clearly indicates that the heating value increases monotonically with the increase in combustion temperature at all pressures. However, three distinct regions along temperature can be observed, which have different rate of the increase of heating value with temperature. The first and last regions have nearly the same rate of increase of the heating value with temperature while the middle region has abruptly faster rate [6]. Fig.7 also shows that the first region becomes shorter with the increase of pressure. The increase on heating value with the increase in temperature would be due to the change of energy level of reacting molecules with the increase in combustion temperature.

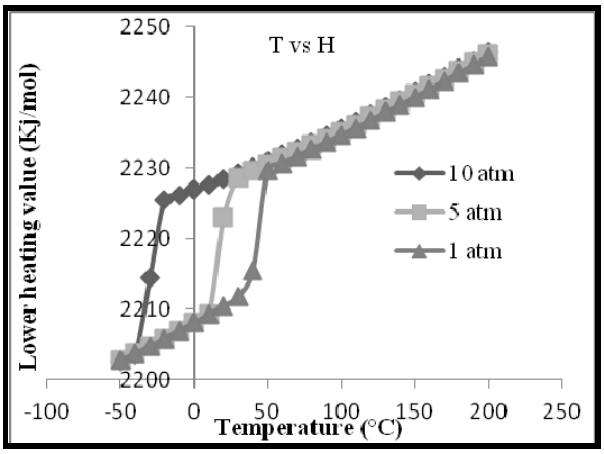

Figure7. Effect of combustion temperature on the heating value of LPG

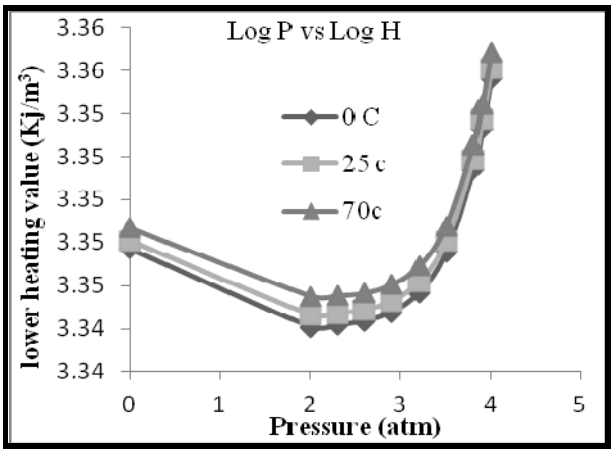

Figure8. Effect of combustion pressure on the heating value of LPG

The effect of combustion pressure on heating value of LPG is studied over a pressure range of 0 to 4 atm under three separate temperatures of 0, 25, and 70°C. Fig. 8 shows that, regardless of combustion temperature considered, the heating value initially decreases to a minimum level and then increases abruptly with the increase in pressure. This complex behavior of heating value with combustion pressure is expected to involve multiple contributing factors, which are still under research.

4. Conclusions

The separate effects of additives or foreign components present in LPG, proportion of primary LPG components, and combustion temperature and pressure on the heating value of LPG are studied in this study. It is found that the presences of additives or foreign components (e.g., ethane, hydrogen

sulfide, moisture, and mercaptan) always decrease the heating value. Hence, it is required to minimize the amount of the additives if the high heating value is desired. It is also found that the heating value of LPG decreases if the proportion of propane is increased through the decrease in the proportion of butane. Hence, it is required to have more proportion of butane in the LPG to ensure a higher heating value. Analysis shows that the heating value always increases with the increase in combustion temperature. Three distinct regions with different rates of increase can clearly be observed in the curve of heating value vs. combustion temperature. However, regardless of combustion temperature, the effect of combustion pressure on the heating value is complex. The heating value decreases with the increase in pressure initially up to a critical pressure level; once the pressure level is exceeded, the heating value increases with increasing pressure. Those who are involved with the research, manufacturer, bottling, and distribution of LPG are expected to be benefited immensely by the results of this study.

Acknowledgements

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References

[1] www.lpgbangladesh.com.
[2] www.aspentech.com
[3] Smith, J.M., H.C. Van Ness and M.M. Abbott, Introduction to Chemical Engineering Thermodynamics, 6th edition, Singapore: McGraw-Hill, (2001)
[4] Y. A. Cengel, M. A. Boles, Thermodynamics an Engineering Approach, 5th edition, McGraw-Hill, Singapore, 2007, pp. 313
[5] C. Borgnakke, Richard E. Sonntag, Fundamentals of Thermodynamics, 1st edition, Apprentice Hall, India, 2008, pp. 123-134
[6] J. M. Moran, Howard N. Sapiro, Fundamentals of Engineering Thermodynamics, 6th edition, John Wiley & Sons, New York, 2010, pp. 33-48

Vitae

Include a short biography for each author along with a frontal photograph.

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