MEASUREMENT OF METHANE CALORIFIC VALUE USING METAL JACKET BURNER

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Abstract − Reference gas calorimeter was built based on the isoperibolic method. Unlike the other reference gas burner which is usually made of glass, the developed gas burner was made of stainless steel and gross calorific value of methane was measured. The result shows 0.4% difference with the value specified by ISO 6976 and the uncertainty is 1.1%. The metal jacket burner shows the promise of the standardization of the gas burner and development of the portable device.

Keywords: calorimeter, calorific value, gas burner, methane, metal burner

1. INTRODUCTION

World energy crisis expedited natural gas development and the natural gas industry is expected to grow by large amount in the future. Natural gas is composed of several components such as methane, ethane, propane and buthane. The composition is varied depending on the origin and time, therefore the calorific value of the natural gas varies. Billing of the natural gas is changing from the gas volume to the calorific value of the gas. The accurate measurement of the gas calorific value is necessary for the gas trade between countries. Currently, gas calorific value is usually calculated on the basis of gas chromatography in accordance with International Standard ISO 6976. However, the calorific value specified in ISO 6976 is based on the measurements made in the 1930s and 1970s and the gas chromatography is not as accurate as the direct combustion method. The superior calorific values of gas can be determined accurately only by complete combustion under the constant pressure condition in the air. All the products are also gaseous foam except water and the temperature of the products are the same as the reactants.

In PTB, an isoperibolic gas calorimeter was developed under GERG project [1]. The result showed 0.006% difference with the value of ISO 6976 and the uncertainty was 0.05%. Similar gas calorimeter was built in LNE and the measurement deviated 0.58% compared to that of ISO 6976 [2]. The above calorimeters have gas burner made of glass. The advantage of glass is its transparency and low heat capacity but the disadvantage is the brittleness and inaccurate manufacturing. In KRISS, an isoperibolic gas calorimeter containing metal burner was developed and the methane calorific value was measured. The result showed 0.4% difference with the value of ISO 6976 and the expanded uncertainty was 1.1%. The metal burner has hardness and can be made very close to the original design and does not show

difference between burners. Therefore, the standardization of the gas burner and gas calorimeter is possible so that there is no conflict in billing natural gas. Furthermore, it can be made smaller so portable gas calorimeter can be manufactured.

2. EXPERIMENTAL APPARATUS AND EXPERMENTAL PROCEDURE

The gas calorimeter is composed of gas supply unit, constant temperature bath containing combustion unit (calorimeter vessel and gas burner) and combustion gas analyser as shown in Fig. 1. The calorimeter vessel is made of stainless steel with the insulating materials inside to prevent heat leakage. Gas burner is installed in the calorimeter vessel. The gas burner is made of stainless steel and it has window in order to observe the flame during the combustion as shown in Fig. 2. In the calorimeter vessel, water temperature is homogenized by stirrer and two thermistors(GE sensing AS115) and one PRT 25Ω(Fluke 5628) are installed to measure the water temperature. Thermocoax two-wire heating resistance is wound around the burner to determine the heat capacity of the calorimeter vessel. The bath temperature is set to 25°C for the whole experimental process. The same power as the methane calorific value is dissipated by the heating wire and temperature rise of the water in the calorimeter vessel is recorded to evaluate the heat capacity of the calorimeter vessel.

For the complete combustion of methane, oxygen and argon gas are supplied to the gas burner. The methane is supplied by one nozzle at the center of the burner and another nozzle surrounds the center nozzle providing oxygen. Argon gas is injected for the stable of the flame. All the gas flow rate are controlled and measured by MFC. The methane gas is filled in the cylinder of 50mL and the mass of the supplied gas is measured by measuring the cylinder weight before and after the combustion experiment. Combustion of methane is initiated by ignition using high voltage (16.5kV) transformer. The combustion of methane continues for approximately 30 minutes and almost 1g of methane is burnt. The burnt gas flows into the H_2O absorption tubes filled with molecular sieves to measure the weight of the formed water during the combustion process. In order to confirm the complete combustion, CO IR analyser (Thermo Scientific Model 48i) monitors the CO concentration of the burnt gas.
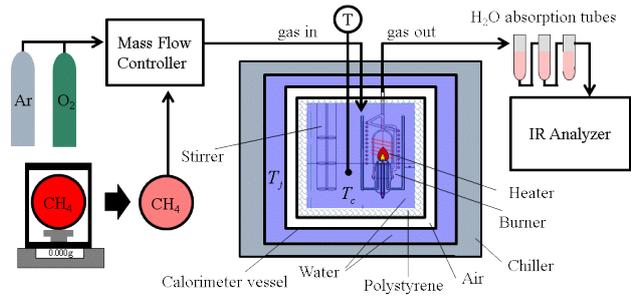
Fig. 1. Experimental apparatus of gas calorimeter

Fig. 2. Upper part(Left) and lower part(Right) of the Metal jacket burner

3. RESULTS

Electrical calibration was performed before the combustion experiment and the result is shown in Fig. 3. The applied power to the heating resistance was 26.97W which is almost same as calorific value of methane. The heat capacity (C_{cal}) of the calorimeter vessel can be calculated by (1). In (1), E_{elec} indicates the electrical energy liberated in the calorimeter vessel and ΔT_{elec} means the temperature rise during the electrical heating. The calculated heat capacity of the calorimeter vessel was 29.22kJ/°C
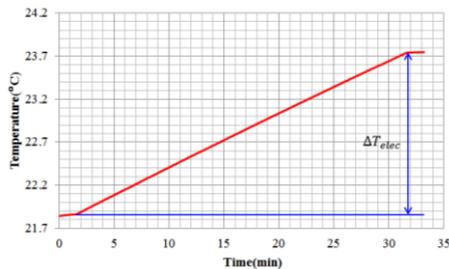

Fig. 3. Temperature profile of the electrical calibration

$$C_{cal} = \frac{E_{elec}}{\Delta T_{elec}} \qquad (1)$$

After the electrical calibration, combustion experiment has been performed under the optimum gas flow condition. The optimum condition was sought by varying the flow rate of the oxygen and monitoring the CO concentration. Fig. 4 shows the temperature profile of the methane combustion. The calorific value of the methane can be calculated by (2) in which, ΔT_{comb} indicates the temperature increase by the methane combustion and Δm_{gas} is the mass of the burnt methane. The measured calorific value of the methane was 55.29 kJ/g which is 0.4% difference with the value specified in ISO 6976. The uncertainty of the experiment was evaluated as 1.1%. The repeatability and the measurement of the heat capacity of the calorimeter vessel were the major factors influencing the uncertainty.
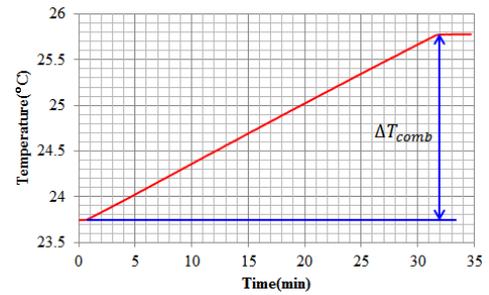

Fig. 4. Temperature profile of the methane combustion.

$$H_s = \frac{C_{cal}\Delta T_{comb}}{\Delta m_{gas}} \qquad (2)$$

4. CONCLUSIONS

In this study, reference gas calorimeter was successfully developed using metal jacket burner for the first time. The calorific value of the methane was measured and the result showed the promise of the metal jacket burner. The developed calorimeter need to be improved for the better measurement. In order to achieve more accurate data, the amount of the unburnt gas should be measured more accurately and the exact amount of electric power need to be measured. For the future work, the smaller burner made of stainless steel needs to be developed for the portable gas calorimter as well as the improvement of the current calorimter.

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