



CHAPTER III

EXPERIMENTAL

3.1 Materials

The simulated natural gas used in this research consisted of methane, ethane, propane, and carbon dioxide, with a $\text{CH}_4:\text{C}_2\text{H}_6:\text{C}_3\text{H}_8:\text{CO}_2$ molar ratio of 70:5:5:20, which was specially manufactured by Thai Industrial Gas (Public) Co., Ltd. Ultra-high purity oxygen used for performing the combined plasma reforming and partial oxidation of the simulated natural gas was also obtained from Thai Industrial Gas (Public) Co., Ltd.

3.2 Experimental Setup

The schematic of the gliding arc discharge system used in this research is shown in Figure 3.1. The system consisted of 4 sections: feed gas mixing section, reactor section, power supply section, and analytical section.

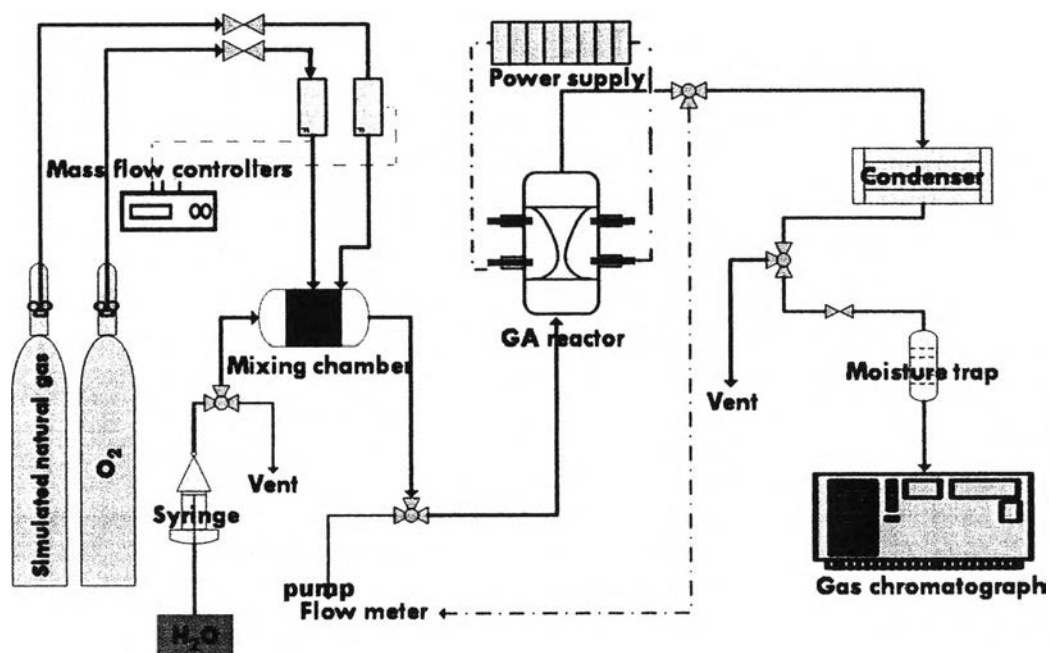


Figure 3.1 Schematic of gliding arc discharge system.

3.2.1 Feed Gas Mixing Section

3.2.1.1 *Gas Mixing Section*

The flow rates of the simulated natural gas and O₂ were controlled by a set of mass flow controllers and transducers supplied by AALBORG. A 7- μ m stainless steel filter was placed upstream of each mass flow controller in order to trap any solid particles in the reactant gases. The check valve was also placed downstream of each mass flow controller to prevent any backflow.

3.2.1.2 *Steam Generation Section*

A water flow rate was controlled by a syringe pump supplied by Cole-Parmer. The temperature of the stainless tube carrying steam was controlled at 120 °C for complete water vaporization. All of the reactant gases and steam were well mixed and introduced upward into the gliding arc discharge reactor at ambient temperature and atmospheric pressure.

3.2.2 Reactor Section

The schematic of the gliding arc discharge reactor is illustrated in Figure 3.2. The reactor was made of a glass tube with 9 cm OD and 8.5 cm ID. The reactor consisted of two diverging knife-shaped electrodes that were made of stainless steel sheets. The width of each electrode was 12 mm. The electrode gap distance between the electrode pairs could be varied. Two teflon sheets were placed at top and bottom of the electrodes to direct the feed gas to pass through the reaction zone.

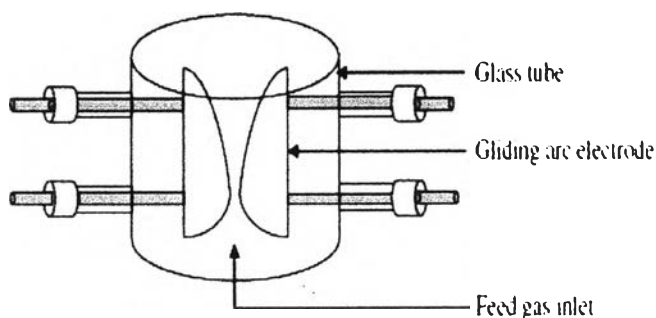


Figure 3.2 Schematic of the gliding arc discharge reactor.

3.2.3 Power Supply Section

The schematic of the power supply unit is depicted in Figure 3.3. The domestic AC input of 220 V and 50 Hz was connected to the DC power supply converter to convert to DC of about 80 V. The DC was supplied through a 500 W power amplifier, which was connected to a Instek function generator to generate waveform and to amplify voltage and frequency. The signal of alternative current was a sinusoidal waveform. The amplified current passed through the transformer to convert to 230 V AC. Thereafter, the variable output was transmitted to a high voltage current by a factor 130. A Lutron power analyzer was used to measure current, frequency, and voltage at the low side of the power supply unit.

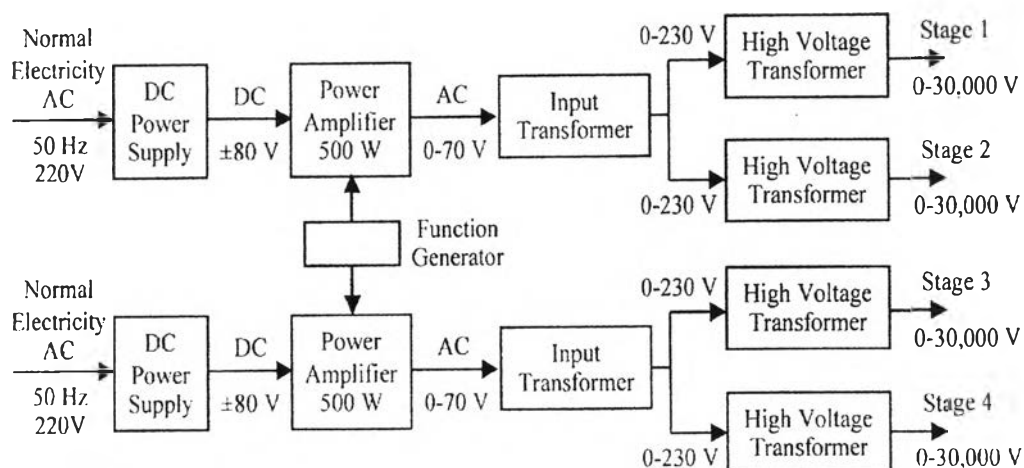


Figure 3.3 Schematic of the power supply unit.

3.2.4 Analytical Section

The feed mixture and the effluent gas were analyzed by an on-line gas chromatograph (HP, 5890) equipped with a thermal conductivity detector (TCD) and a flame ionization detector (FID). The quantitative analysis of the percent volumes of all gaseous components was carried out by correlating their peak area responses obtained from the GC chromatograms. The HP 5890 gas chromatograph was installed with a 10-port valve in order to separate the analyzed gas into two parts with independent sample loops. The first part was connected to a Carboxen 1000 column with the TCD. The second part was sent to a PLOT Al₂O₃”S” column connected with the FID. The GC conditions are summarized as follows:

Injector type:	Automatic sampling valve (programmable)
Injection temperature:	120 °C
Oven temperature:	Initial temperature 40 °C, ramp up at 70 °C/min to 100 °C followed by ramping up again at 30 °C/min to 190 °C and then hold for 17 min
Detectors:	Thermal conductivity detector (TCD) and flame ionization detector (FID)
Detector temperature:	190 °C

GC columns:	Carboxen 1000 (15' x 1/8') and PLOT Al ₂ O ₃ "S" (30 m x 0.53 mm)
Carrier gas:	High purity helium (99.995 %)
Carrier gas flow rates:	35 cm ³ /min for Carboxen 1000 column and 105 cm ³ /min for PLOT Al ₂ O ₃ "S" column

3.3 Reaction Performance Evaluation

The conversion of reactant gases was calculated using the following equation:

$$\% \text{ conversion} = \frac{(\text{moles of reactant in} - \text{moles of reactant out})(100)}{\text{moles of reactant in}}$$

The percent selectivity for products containing carbon atoms was calculated on the basis of the amount of carbon converted from the reactants into any specified products. In case of hydrogen product, the hydrogen selectivity was calculated based on hydrogen converted from the reactants.

$$\% \text{ selectivity for any hydrocarbon product} = \frac{[P](C_P)(100)}{\sum [R](C_R)}$$

where

[P]	=	moles of product in effluent
[R]	=	moles of reactant in feed to be converted
C _P	=	numbers of carbon atom in a product molecule
C _R	=	numbers of carbon atom in a reactant molecule

$$\% \text{ selectivity for hydrogen} = \frac{[P](H_P)(100)}{\sum [R](H_R)}$$

where

H _P	=	numbers of hydrogen atom in a product molecule
H _R	=	numbers of hydrogen atom in a reactant molecule

The product yield was calculated as follows:

$$\begin{aligned} \text{\% yield of C}_2 \text{ hydrocarbons} &= \sum(\text{\% conversion of CH}_4, \text{C}_2\text{H}_6, \text{C}_3\text{H}_8, \text{CO}_2) \\ &\quad \times \sum(\text{\% selectivity of C}_2\text{H}_2, \text{C}_2\text{H}_4) / (100) \end{aligned}$$

$$\text{\% yield of H}_2 = \frac{\sum(\text{\% conversion of CH}_4, \text{C}_2\text{H}_6, \text{C}_3\text{H}_8) \times (\text{\% selectivity of H}_2)}{100}$$

The power consumption was calculated in a unit of Ws per a C-containing reactant molecule converted or per a hydrogen molecule produced (Ws/M) using the following equation:

$$\text{Power consumption} = (P) (60) / (\tilde{N}) (M)$$

where

P	=	Power (W)
\tilde{N}	=	Avogadro's number = 6.02×10^{23} molecules·g·mole ⁻¹
M	=	Rate of converted carbon in feed or rate of produced hydrogen

3.4 Studied Conditions

For any studied conditions, the system was operated to reach steady state before taking samples for analysis. The steady state was justified when the composition of effluent gas was invariant with time. After the composition of the reactant gases fed into the system was constant, the power supply unit was turned on. The product gas was then analyzed to obtain the reactant conversions, product selectivities, and product yields.

All operating conditions used in this research are summarized as follows:

- HCs-to-O₂ feed molar ratio: 2/1–9/1
- Applied voltage: 13.5–20.5 kV
- Input frequency: 290–500 Hz
- Electrode gap distance: 4–8 mm