CHAPTER IV
RESULTS AND DISCUSSION

According to the previous work (Chavadej *et al.*, 2008), the corona discharge system was proved to provide acceptably high ethylene epoxidation performance. Hence, in this research, the corona discharge system was selected to further study the effects of distance between plate electrode and ethylene feed position, as well as other operating parameters, for enhancing the performance of ethylene oxide (desired product) production.

4.1 Effect of Distance between Plate Electrode and C_2H_4 Feed Position

The effect of distance between plate electrode and C_2H_4 feed position was initially studied in order to obtain the most suitable C_2H_4 feed position for the ethylene epoxidation reaction. In this work, the distance between plate electrode and C_2H_4 feed position was investigated in the range of 0.1–0.5 cm, while the other operating parameters were fixed at an O_2/C_2H_4 feed molar ratio of 0.5:1, an applied voltage of 15 kV, an input frequency of 500 Hz, a total feed flow rate of 100 cm^3/min, and a gap distance between pin and plate electrodes of 1 cm.

4.1.1 Effect of Distance between Plate Electrode and C_2H_4 Feed Position on Ethylene and Oxygen Conversions and Ethylene Oxide Yield

Under the studied conditions, the lowest distance between plate electrode and C_2H_4 feed position that could generate EO is 0.1 cm. Therefore, the reaction experiments were conducted using the distance between plate electrode and C_2H_4 feed position higher than 0.1 cm. The results of O_2 and C_2H_4 conversion and EO yield are illustrated in Figure 4.1. The C_2H_4 and O_2 conversions only slightly varied in narrow ranges under the studied distance range between plate electrode and C_2H_4 feed position of 0.1–0.5 cm. In contrast, the EO yield tended to increase with increasing distance between plate electrode and C_2H_4 feed position to 0.2 cm and then gradually decreased with further increasing distance between plate electrode and C_2H_4 feed position to 0.5 cm. The results imply that at the distance between plate electrode and C_2H_4 feed position of 0.2 cm, C_2H_4 could react the most selectively with the oxygen radicals in the plasma zone to produce EO. However, the larger the distance between plate electrode and C_2H_4 feed position than 0.2 cm, the lower the opportunity of C_2H_4 to react with the oxygen radicals to produce EO, probably due to the higher recombination possibility between unstable oxygen radicals before reacting with C_2H_4 molecules.

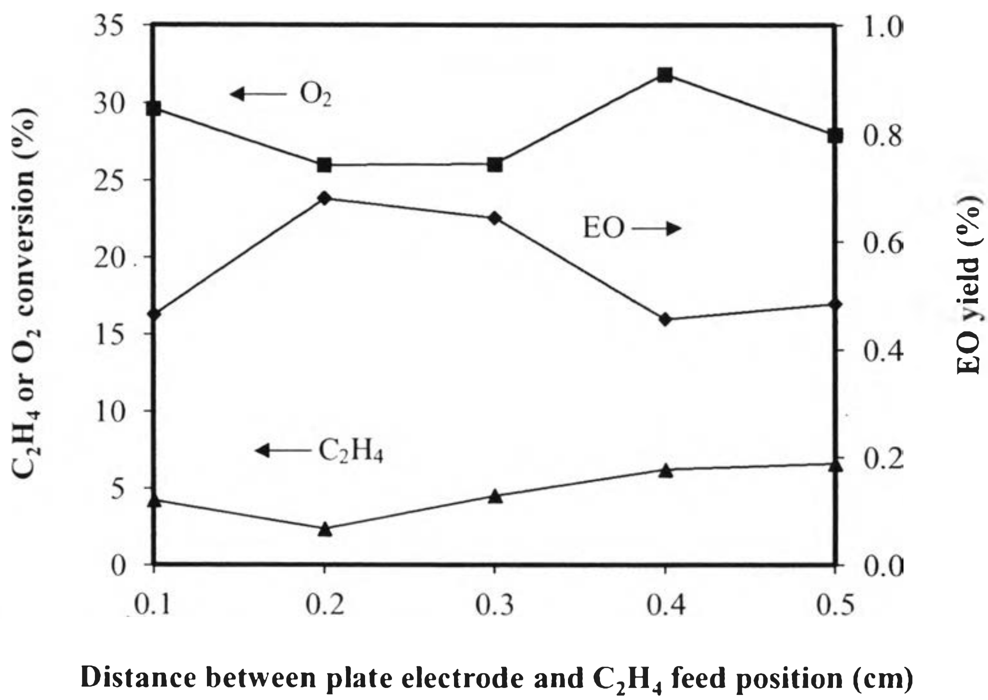

Figure 4.1 C_2H_4 and O_2 conversions and EO yield as a function of distance between plate electrode and C_2H_4 feed position (O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 15 kV, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.1.2 Effect of Distance between Plate Electrode and C_2H_4 Feed Position on Product Selectivities

Figure 4.2 shows the effect of distance between plate electrode and C_2H_4 feed position on the selectivities for EO, CO, H_2, CH_4, C_2H_2, and C_3H_8. The EO, CH_4, and C_3H_8 selectivities tended to increase with increasing distance between plate electrode and C_2H_4 feed position to 0.2 cm and then decreased with further increasing distance between plate electrode and C_2H_4 feed position, which were in the same trend as the EO yield, whereas the CO, H_2, and C_2H_2 selectivities remained almost unchanged. Under the studied conditions, the main by-products were CO, H_2, and C_2H_2 with less amount of CH_4. The higher molecular weight hydrocarbon, i.e. C_3H_8, was also found in very small fraction.

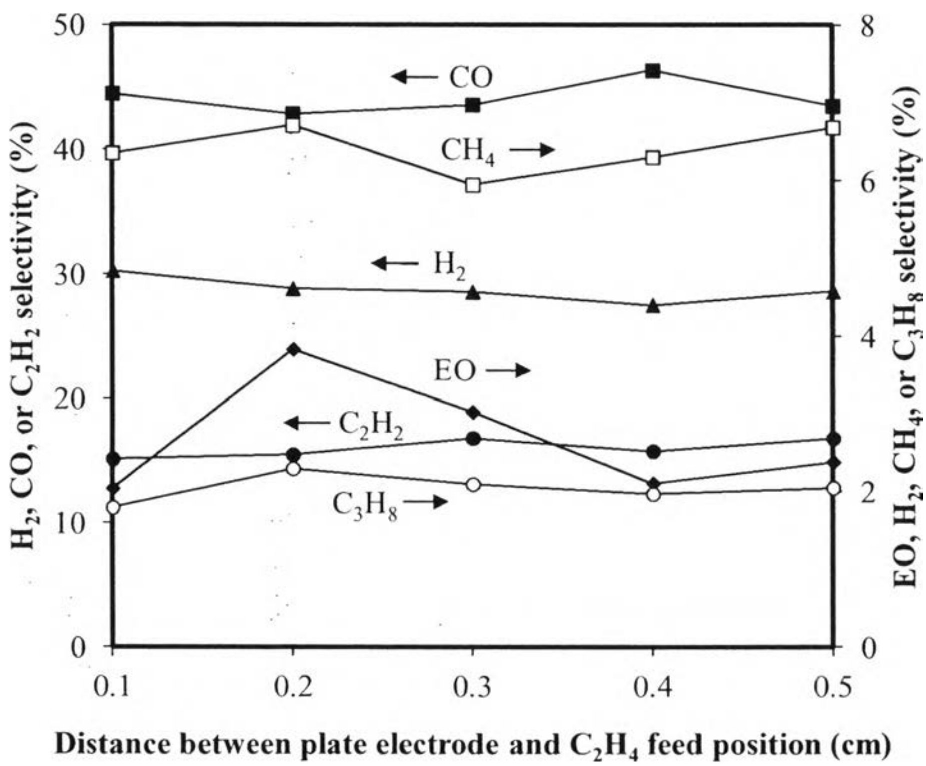

Figure 4.2 Product selectivities as a function of distance between plate electrode and C_2H_4 feed position (O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 15 kV, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.1.3 Effect of Distance between Plate Electrode and C_2H_4 Feed Position on Power Consumptions

Figure 4.3 shows the effect of distance between plate electrode and C_2H_4 feed position on the power consumptions. The power consumption per molecule of converted C_2H_4 reached a maximum at a distance between plate electrode and C_2H_4 feed position of 0.2 cm. At a distance between plate electrode and C_2H_4 feed position higher than 0.2 cm, the power consumption per molecule of converted C_2H_4 rapidly decreased. However, there was a rapid decrease in the power consumption per molecule of produced EO with increasing distance between plate electrode and C_2H_4 feed position to 0.2 cm, but it increased with further increasing distance between plate electrode and C_2H_4 feed position. These results imply that the C_2H_4 molecules could be unfavorably broken down in the plasma zone before reacting with the oxygen radicals, and the efficiency of producing EO was reduced. In addition, it can be clearly seen that the power consumption per molecule of produced EO was about one order of magnitude higher than that per molecule of converted C_2H_4, so the former must be taken into more consideration when evaluating the system performance. Therefore, a distance between plate electrode and C_2H_4 feed position of 0.2 cm was considered to be an optimum value and selected for further experiments because it provided the highest EO selectivity, the highest EO yield, and the lowest power consumption per molecule of produced EO.

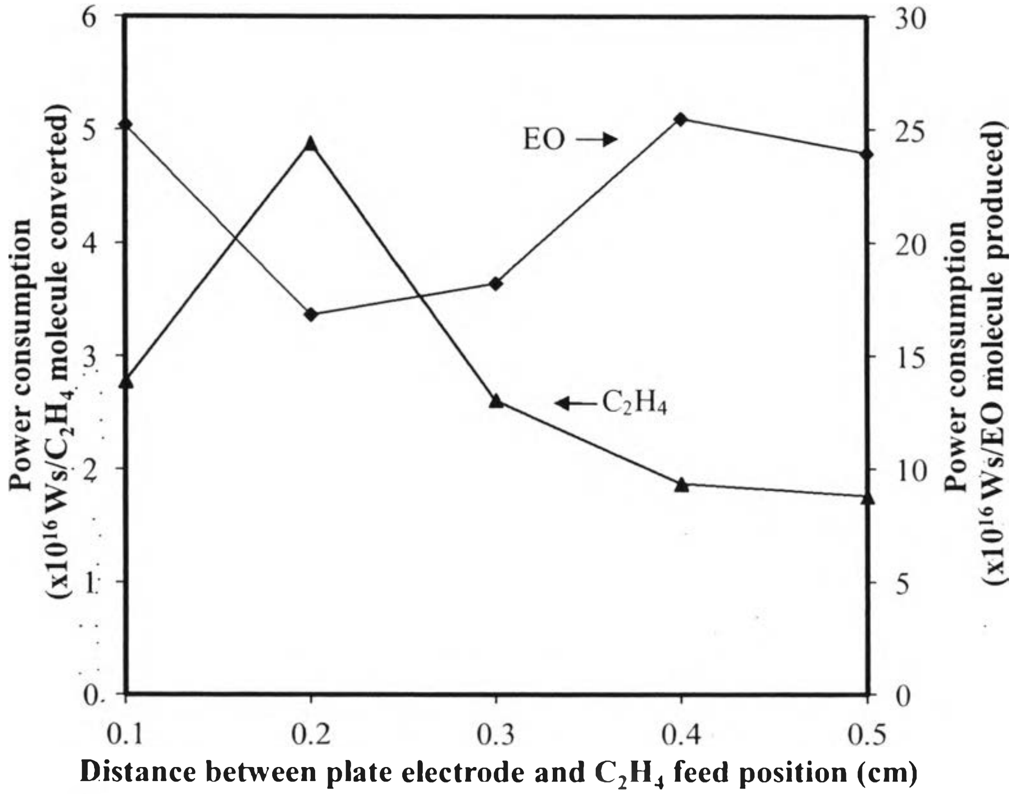

Figure 4.3 Power consumptions as a function of distance between plate electrode and C_2H_4 feed position (O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 15 kV, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.2 Effect of O_2/C_2H_4 Feed Molar Ratio

To determine the influence of the feed gas composition on the ethylene epoxidation reaction under the investigated corona discharge environment, the O_2/C_2H_4 feed molar ratio was next investigated in the range of 0.25:1–1:1 (O_2-lean conditions), while the other operating parameters were fixed at a distance between plate electrode and C_2H_4 feed position of 0.2 cm, an applied voltage of 15 kV, an input frequency of 500 Hz, a total feed flow rate of 100 cm^3/min, and a gap distance between pin and plate electrodes of 1 cm.

4.2.1 Effect of O_2/C_2H_4 Feed Molar Ratio on Ethylene and Oxygen Conversions and Ethylene Oxide Yield

The effect of O_2/C_2H_4 feed molar ratio on the C_2H_4 and O_2 conversions and EO yield is shown in Figure 4.4. The increase in O_2/C_2H_4 feed molar ratio slightly affected the C_2H_4 conversion, whereas the O_2/C_2H_4 feed molar ratio mainly affected the O_2 conversion. The O_2 conversion tended to increase with increasing O_2/C_2H_4 feed molar ratio from 0.33:1 to 0.75:1 and then decreased with further increasing O_2/C_2H_4 feed molar ratio. It can be observed that the O_2 conversion was much higher than the C_2H_4 conversion. This can be explained in that the bond dissociation energy of C_2H_4 (16.7 eV) is much higher than that of O_2 (12.2 eV), accordingly causing O_2 molecules to be converted more easily than C_2H_4 molecules. It could also be seen that the EO yield tended to increase with increasing O_2/C_2H_4 feed molar ratio from 0.25:1 up to 0.5:1 and then rapidly decreased with further increasing O_2/C_2H_4 feed molar ratio. These results clearly indicate the significance of feed gas composition (i.e. C_2H_4 and O_2) on the ethylene epoxidation performance.

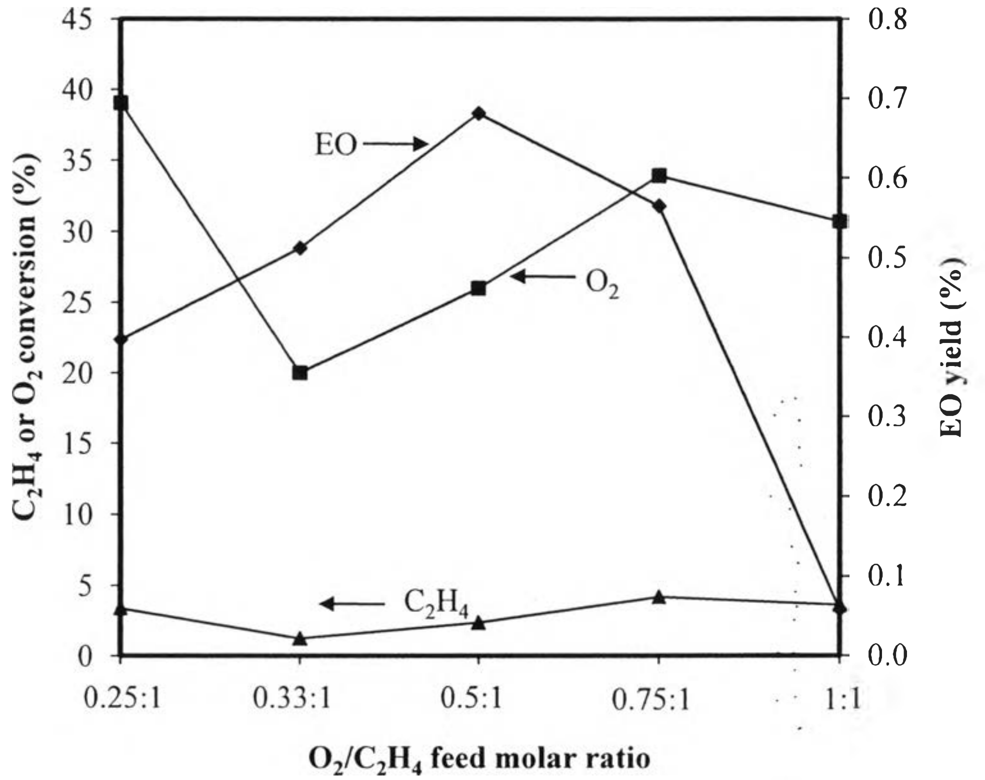

Figure 4.4 C_2H_4 and O_2 conversions and EO yield as a function of O_2/C_2H_4 feed molar ratio (distance between plate electrode and C_2H_4 feed position = 0.2 cm, applied voltage = 15 kV, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.2.2 Effect of O_2/C_2H_4 Feed Molar Ratio on Product Selectivities

Figure 4.5 shows the effect of O_2/C_2H_4 feed molar ratio on the product selectivities. The EO selectivity increased to reach a maximum at an O_2/C_2H_4 feed molar ratio of 0.33:1 and then rapidly decreased with further increasing O_2/C_2H_4 feed molar ratio higher than 0.33:1. For the other by-product selectivities, except CO and CH_4, the selectivities for H_2, C_2H_2, and C_3H_8 tended to increase and then decreased with further increasing O_2/C_2H_4 feed molar ratio higher than 0.33:1. For the CH_4 selectivity, it tended to increase with increasing O_2/C_2H_4 feed molar ratio from 0.25:1–0.75:1 and then decreased, whereas the CO selectivity decreased to reach a minimum at an O_2/C_2H_4 feed molar ratio of 0.33:1 and then increased with further increasing O_2/C_2H_4 feed molar ratio higher than 0.33:1. The results indicate that the epoxidation reaction to produce EO was more likely to occur under O_2-lean conditions.

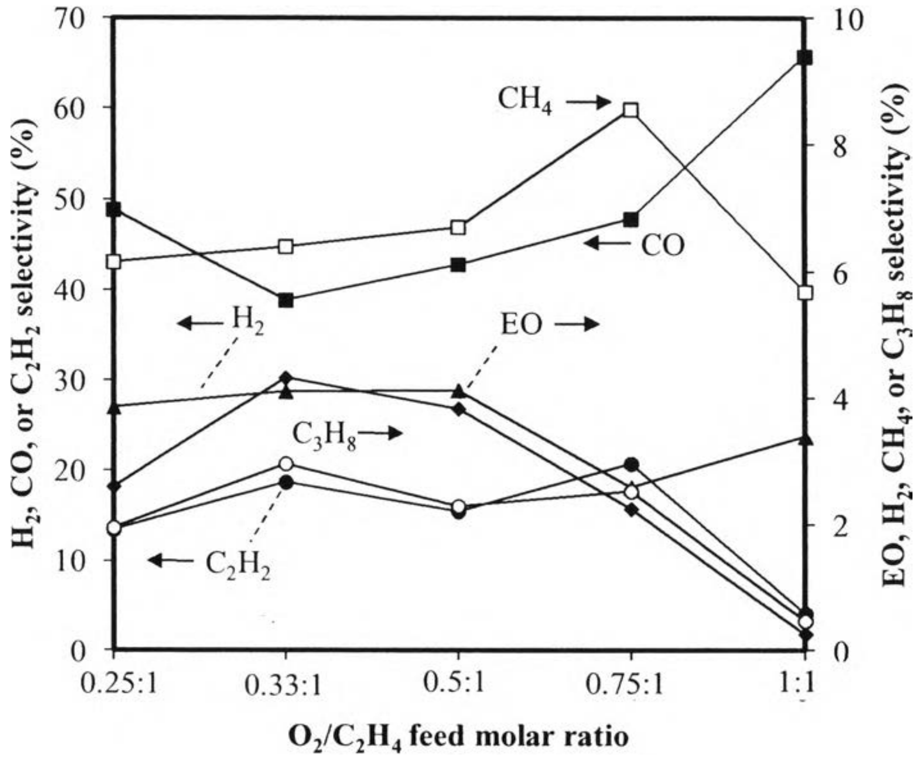

Figure 4.5 Product selectivities as a function of O_2/C_2H_4 feed molar ratio (distance between plate electrode and C_2H_4 feed position = 0.2 cm, applied voltage = 15 kV, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.2.3 Effect of O_2/C_2H_4 Feed Molar Ratio on Power Consumptions

The power consumptions required to convert C_2H_4 molecule and to produce EO molecule at different O_2/C_2H_4 feed molar ratios are shown in Figure 4.6. The power consumption per molecule of converted C_2H_4 reached a maximum at an O_2/C_2H_4 molar ratio of 0.33:1, which corresponded well with the obtained highest EO selectivity. However, the power consumption per molecule of produced EO remained almost unchanged in the O_2/C_2H_4 feed molar ratio range of 0.25:1–0.75:1, but then rapidly increased with increasing O_2/C_2H_4 feed molar ratio to 1:1, at which the lowest EO selectivity was observed. As mentioned above, the power consumption per molecule of produced EO was much higher than that per molecule of converted C_2H_4, the O_2/C_2H_4 feed molar ratio of 0.5:1 was therefore selected for further experiments because it provided the highest EO yield, as well as comparatively low power consumption per molecule of produced EO.

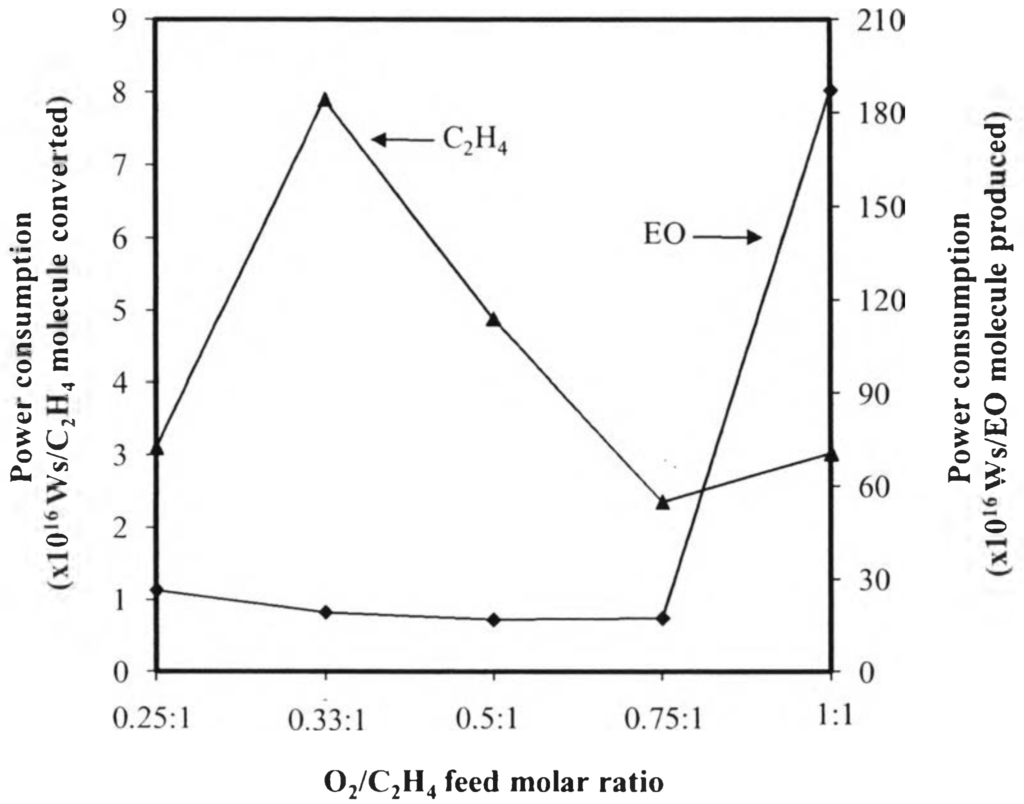

Figure 4.6 Power consumptions as a function of O_2/C_2H_4 feed molar ratio (distance between plate electrode and C_2H_4 feed position = 0.2 cm, applied voltage = 15 kV, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.3 Effect of Applied Voltage

In order to determine the effect of the applied voltage, the reaction experiments were conducted in the applied voltage range of 15–19 kV. The highest applied voltage that could be achieved was 19 kV, which was limited by the formation of coke filaments between the two electrodes during a relatively short operation period, causing instability and thereby permanent extinction of the plasma.

4.3.1 Effect of Applied Voltage on Ethylene and Oxygen Conversions and Ethylene Oxide Yield

Figure 4.7 illustrates the effect of applied voltage on the C_2H_4 and O_2 conversions and EO yield. The O_2 conversion tended to increase with increasing applied voltage in the range of 15–19 kV. In contrast, the C_2H_4 conversion remained almost unchanged. The explanation for the increased O_2 conversion is that a higher voltage results in a higher generated current, as shown in Figure 4.8, which provides more available electrons to initiate the reactions and brings about greater opportunity for collision between O_2 molecules and electrons. However, the almost unchanged C_2H_4 conversion can be explained in that the bond dissociation energy of O_2 (12.2 eV) is much lower than that of C_2H_4 (16.7 eV), particularly causing O_2 molecules to be converted more easily than C_2H_4 molecules, as mentioned above. In addition, it was found that the EO yield tended to increase with increasing applied voltage in the range of 15–18 kV and then drastically decreased because of the formation of coke filaments between the two electrodes in a short operation period.

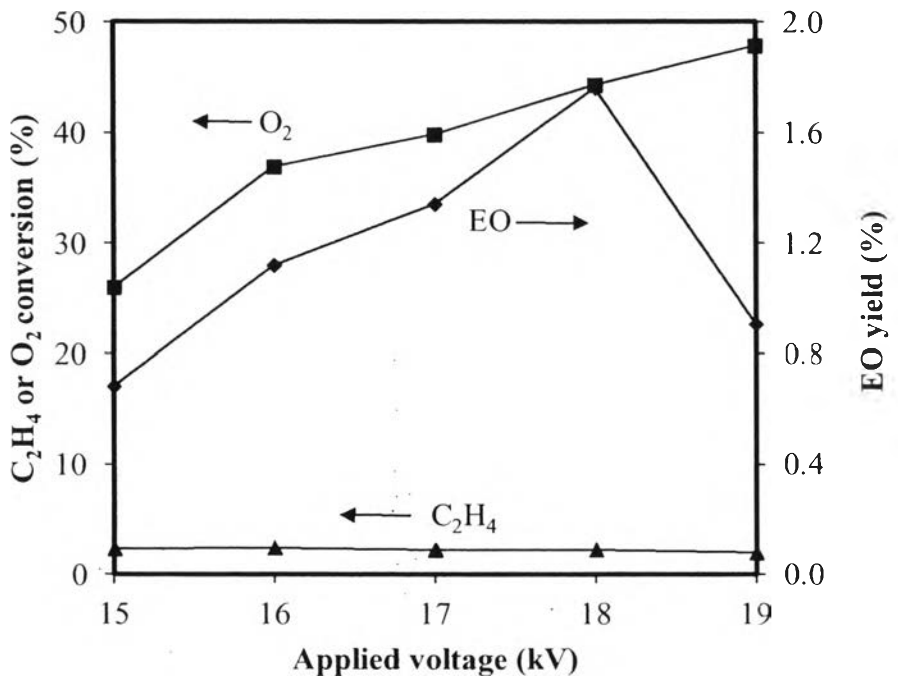

Figure 4.7 C_2H_4 and O_2 conversions and EO yield as a function of applied voltage (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

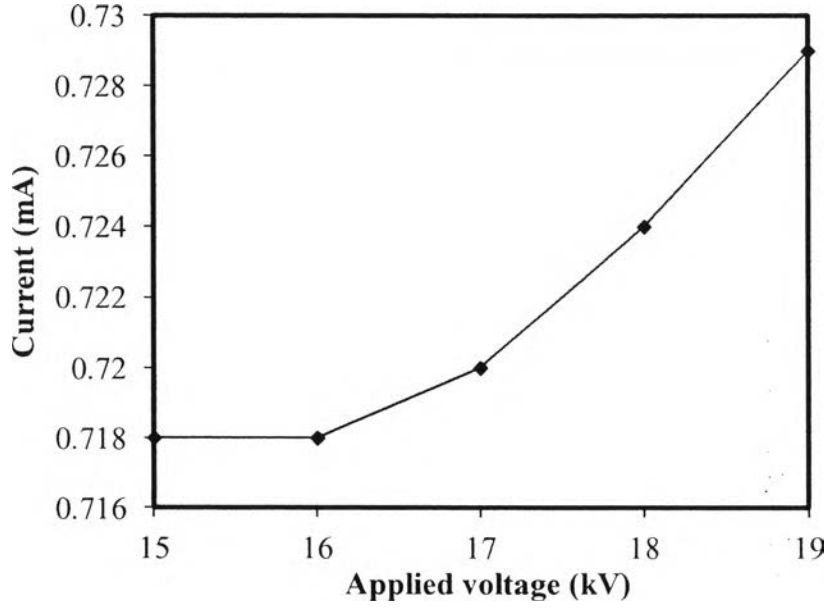

Figure 4.8 Generated current as a function of applied voltage (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.3.2 Effect of Applied Voltage on Product Selectivities

The effect of applied voltage on the selectivities for EO, CO, H_2, CH_4, C_2H_2, and C_3H_8 is shown in Figure 4.9. The EO selectivity rapidly increased with increasing applied voltage in the range of 15–18 kV and then decreased with further increasing applied voltage, possibly due to the earlier explanation for the limitation of coke formation. The selectivities for H_2, CH_4, C_2H_2, and C_3H_8 reached the minimum values at the applied voltage of 17 kV and then increased with further increasing applied voltage between 17 and 19 kV. Interestingly, no CO_2 was detected possibly because the system was operated under the O_2-lean condition (the O_2/C_2H_4 feed molar ratio of 1:2). The CO selectivity increased with increasing applied voltage in the range of 15–17 kV and then decreased with further increasing applied voltage. These results suggest that the higher number of oxygen active species is more favorable for EO production than CO production.

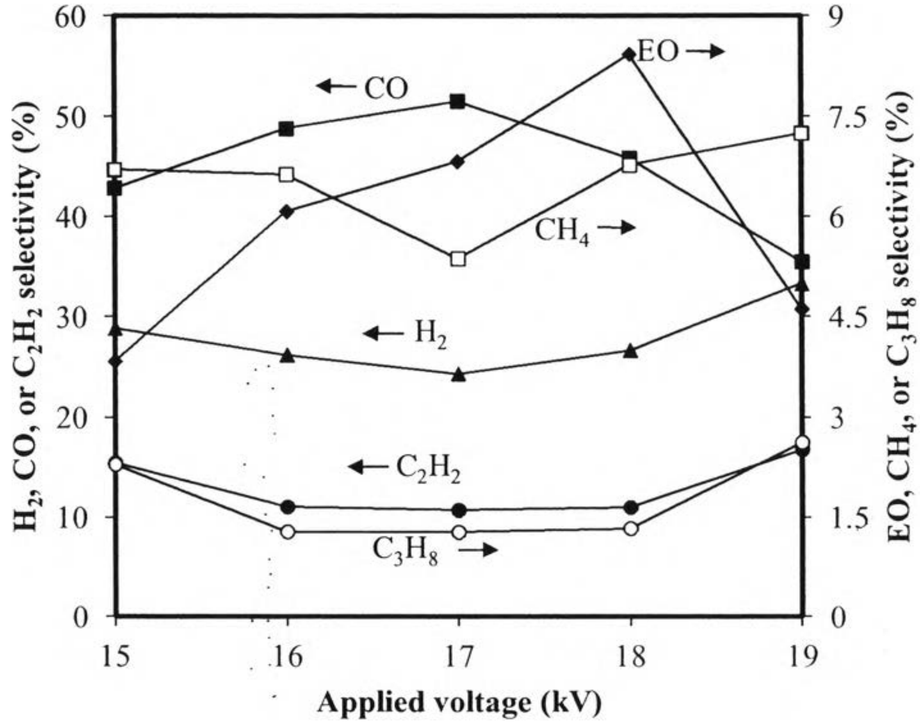

Figure 4.9 Product selectivities as a function of applied voltage (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.3.3 Effect of Applied Voltage on Power Consumptions

The effect of the power consumptions needed to convert C_2H_4 molecule and to produce EO molecule at different input frequencies are shown in Figure 4.10. The power consumption per molecule of converted C_2H_4 only slightly changed with varying applied voltage, possibly due to the almost unchanged C_2H_4 conversion. On the other hand, the power consumption per molecule of produced EO decreased until reaching a minimum at an applied voltage of 18 kV and then increased with further increasing applied voltage. For further experiments, the applied voltage of 18 kV was selected to employ because it provided the highest EO yield, the highest EO selectivity, and the lowest power consumption per molecule of produced EO.

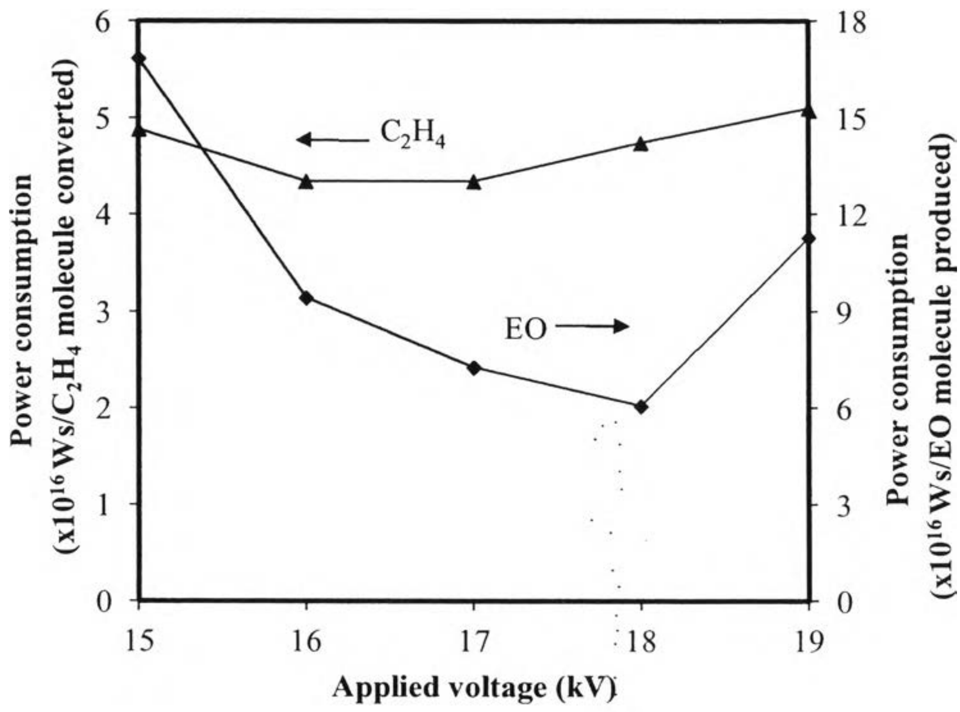

Figure 4.10 Power consumptions as a function of applied voltage (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 1:1, input frequency = 500 Hz, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.4 Effect of Input Frequency

Input frequency is another important parameter that greatly affects the plasma characteristics in terms of stability and efficiency performance. The input frequency was experimentally varied in the range of 400–700 Hz. For operating the corona discharge system in this research, the lowest operating input frequency (400 Hz) was limited by a large amount of coke filaments that was found to deposit on the electrode surface at an input frequency lower than 400 Hz, whereas the plasma could not exist at an input frequency higher than 700 Hz.

4.4.1 Effect of Input Frequency on Ethylene and Oxygen Conversions and Ethylene Oxide Yield

The effect of input frequency on the C_2H_4 and O_2 conversions and EO yield is illustrated in Figure 4.11. The results show that an increase in the input frequency led to a decrease in the O_2 conversion, whereas the C_2H_4 conversion remained almost constant. A possible reason for the decreased O_2 conversion is that a lower generated current at a higher input frequency, as confirmed in Figure 4.12, results in a reduction of the number of available electrons (weaker field strength) for initiating the plasma reaction; therefore, it caused a decrease in the amount of oxygen active species for further reactions, resulting in a decrease in the O_2 conversion. This subsequently led to a lower EO yield at a higher input frequency; however, the EO yield was observed to decrease with decreasing input frequency from 500 to 400 Hz since coke deposition on the electrode surfaces considerably occurred. Hence, the maximum EO yield was found at an input frequency of 500 Hz.

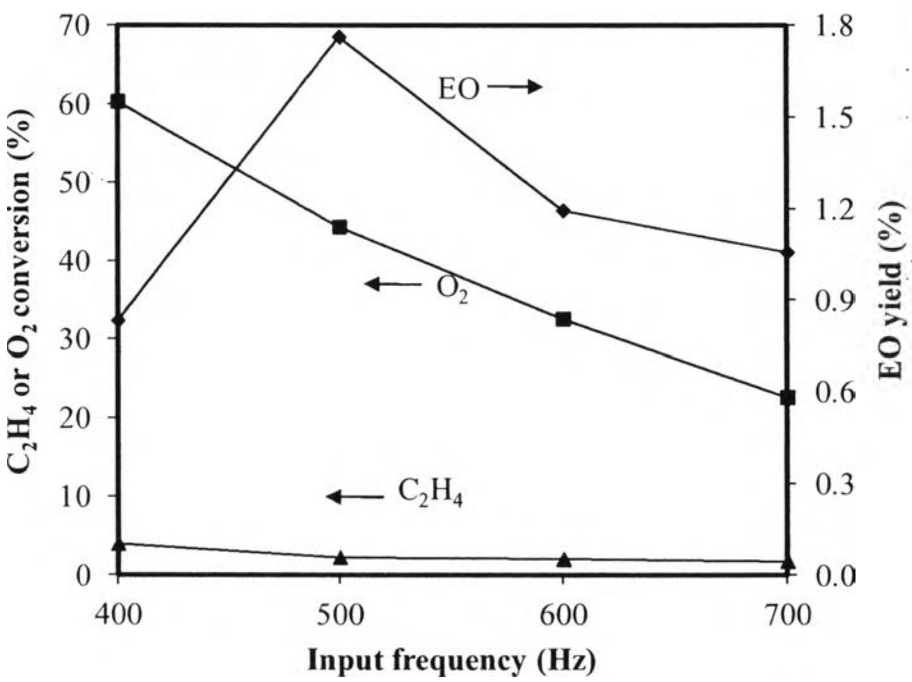

Figure 4.11 C_2H_4 and O_2 conversions and EO yield as a function of input frequency (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

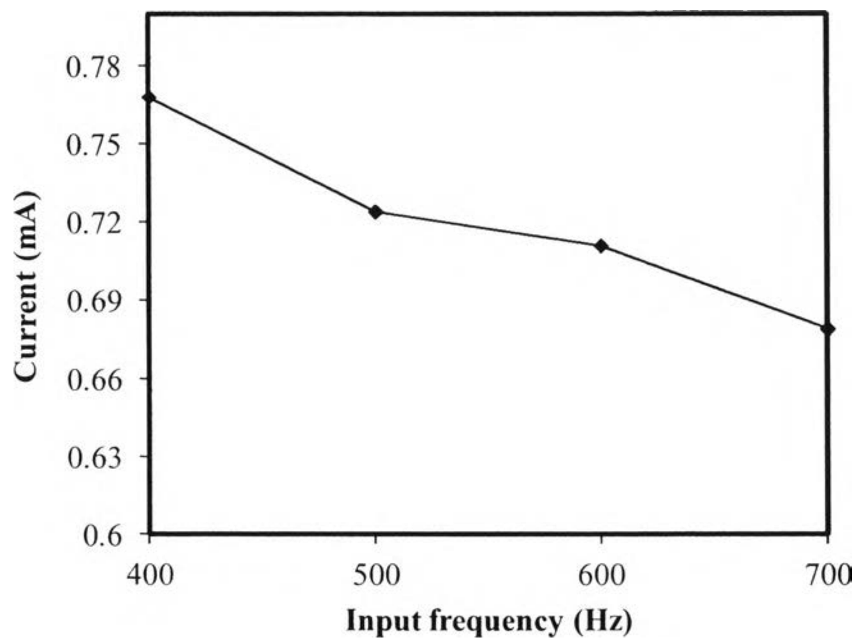

Figure 4.12 Generated current as a function of input frequency (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.4.2 Effect of Input Frequency on Product Selectivities

The effect of input frequency on the product selectivities is shown in Figure 4.13. The EO selectivity at an input frequency lower than 500 Hz decreased because of coke formation, as mentioned above, whereas it tended to decrease with increasing input frequency from 500 to 700 Hz. Hence, the maximum EO selectivity was observed at the input frequency of 500 Hz. The CO selectivity slightly increased with increasing input frequency from 400 to 600 Hz and then dramatically decreased with further increasing input frequency from 600 to 700 Hz. For other by-products, their selectivities tended to decrease with increasing input frequency. This is because a higher frequency gives a lower generated current, resulting in the decrease in amount of active species for further reactions.

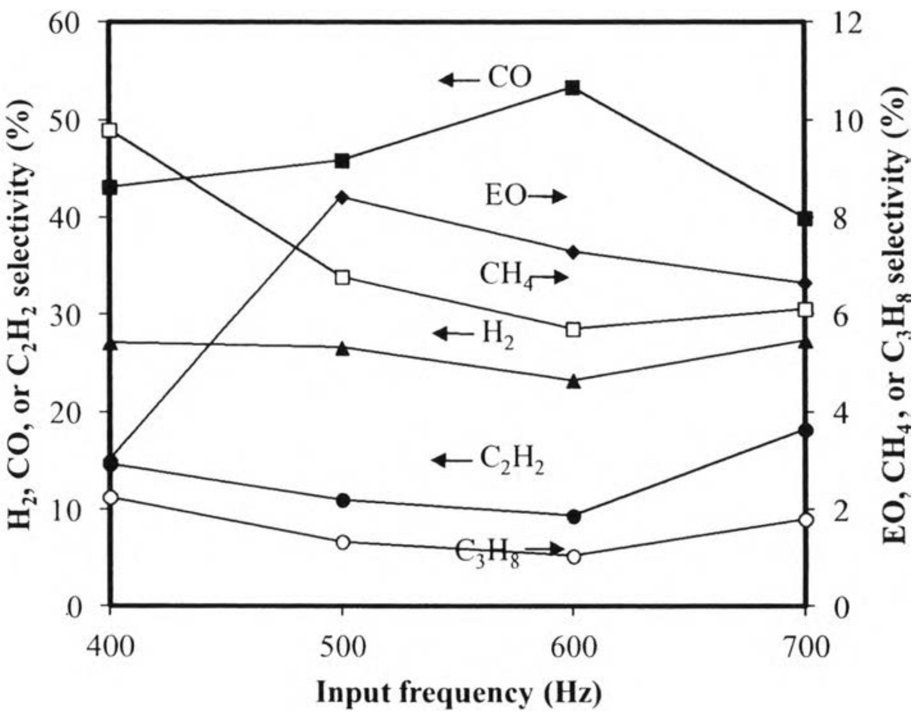

Figure 4.13 Product selectivities of input frequency (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.4.3 Effect of Input Frequency on Power Consumptions

The effect of input frequency on the power consumption to break down each C_2H_4 molecule or to create each EO molecule is shown in Figure 4.14. The power consumption per molecule of converted C_2H_4 tended to increase with increasing input frequency; however, the power consumption per molecule of produced EO decreased with increasing input frequency to 500 Hz and then increased with further increasing input frequency from 500 to 700 Hz. From the overall results, an input frequency of 500 Hz was considered to be an optimum value because it provided the highest EO yield, the highest EO selectivity, and the lowest power consumption per molecule of produced EO.

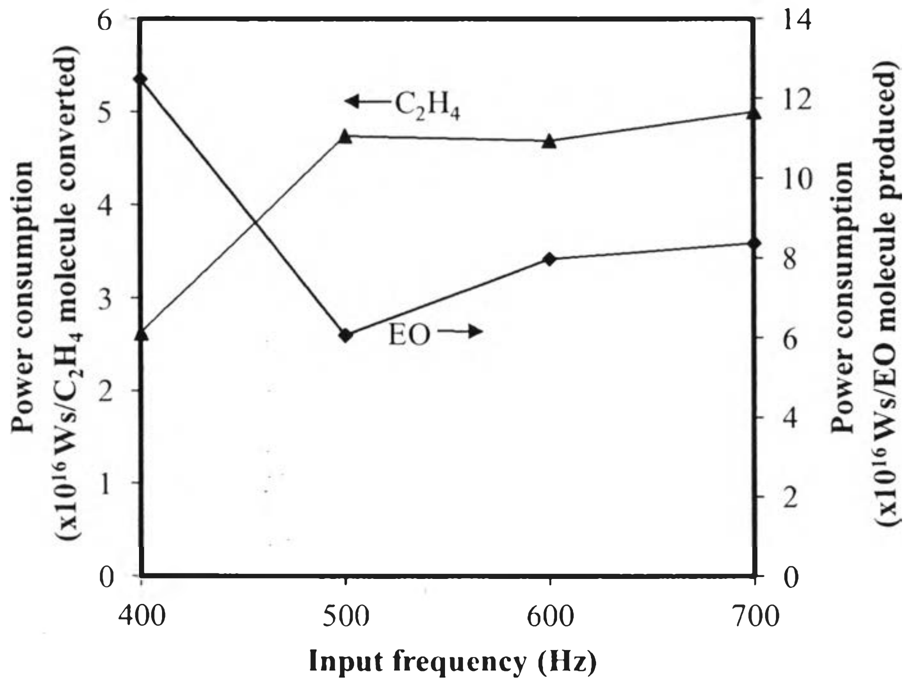

Figure 4.14 Power consumptions as a function of input frequency (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, total feed flow rate = 100 cm^3/min, and gap distance between pin and plate electrodes = 1 cm).

4.5 Effect of Total Feed Flow Rate

The total feed flow rate has a great effect on the residence time of gas molecules in the plasma zone, affecting the overall performance of the plasma system. To investigate the effect of total feed flow rate, the experiments were performed by varying total feed flow rate from 100 to 150 cm^3/min. A total feed flow rate lower than 100 cm^3/min was limited by too low C_2H_4 flow rate to be precisely controlled by a mass flow controller. The reaction experiments were conducted at a gap distance between plate electrode and C_2H_4 feed position of 0.2 cm, an O_2/C_2H_4 feed molar ratio of 0.5:1, an applied voltage of 18 kV, an input frequency of 500 Hz, and a gap distance between pin and plate electrodes of 1 cm.

4.5.1 Effect of Total Feed Flow Rate on Ethylene and Oxygen Conversions and Ethylene Oxide Yield

Figure 4.15 illustrates the influence of the total feed flow rate on the C_2H_4 and O_2 conversions and EO yield. The O_2 conversion gradually decreased with increasing total feed flow rate from 100 to 150 cm^3/min, while the C_2H_4 conversion remained almost unchanged. An increase in the total feed flow rate normally reduces the gas residence time in the reaction system, resulting in having a shorter contact time for C_2H_4 and O_2 molecules to collide with electrons. Therefore, a reduction in the total feed flow rate led to an increase in the EO yield.

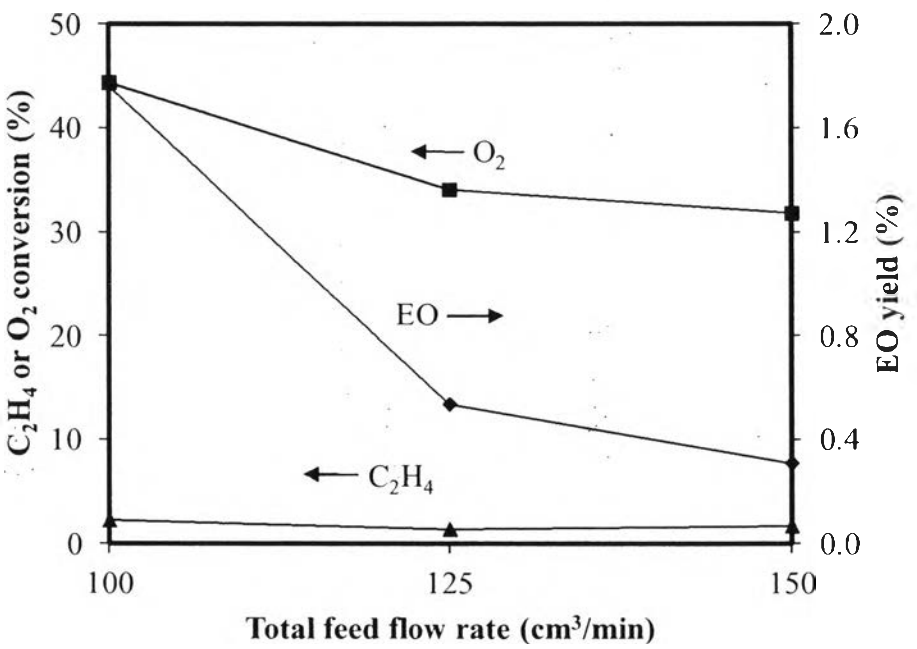

Figure 4.15 C_2H_4 and O_2 conversions and EO yield as a function of total feed flow rate (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and gap distance between pin and plate electrodes = 1 cm).

4.5.2 Effect of Total Feed Flow Rate on Product Selectivities

The feed flow rate dependence of product selectivities is depicted in Figure 4.16. It can be seen that the EO selectivity decreased with increasing total feed flow rate. This is because a higher total feed flow rate reduces the opportunity of collision between electrons/oxygen active species and C_2H_4 molecules, thereby decreasing the epoxidation performance. In contrast, the other product selectivities tended to slightly increase at a higher total feed flow rate (i.e. a shorter residence time), suggesting that the oxidation and coupling reactions are more favorable to occur than the epoxidation reaction when the residence time is decreased.

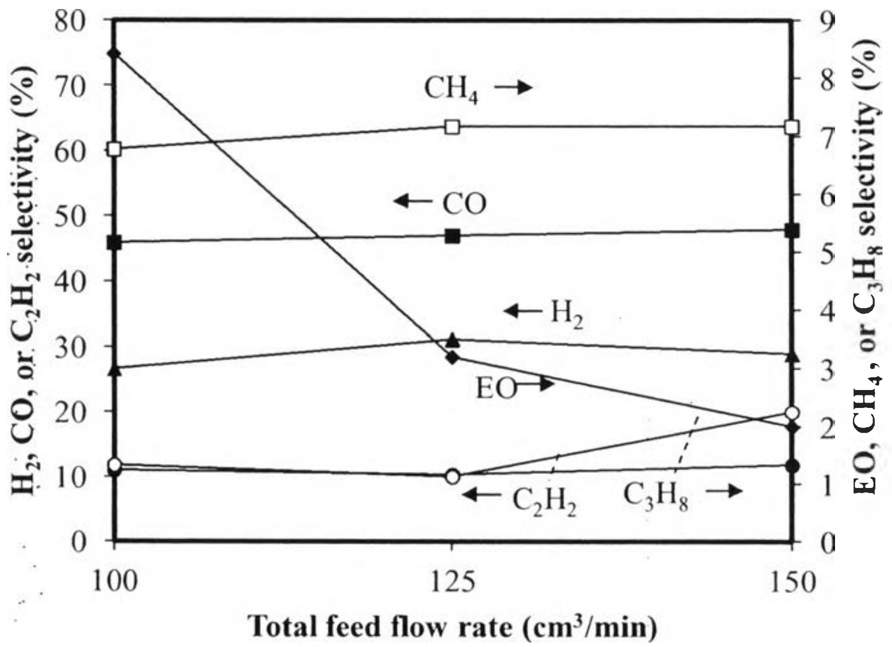

Figure 4.16 Product selectivities as a function of total feed flow rate (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and gap distance between pin and plate electrodes = 1 cm).

4.5.3 Effect of Total Feed Flow Rate on Power Consumptions

Figure 4.17 shows the effect of total feed flow rate on the power consumptions. The power consumption per molecule of converted C_2H_4 increased with increasing total feed flow rate from 100 to 125 cm^3/min and then decreased, while the power consumption per molecule of produced EO sharply increased with increasing total feed flow rate. From the overall results, the lowest total feed flow rate of 100 cm^3/min was considered as an optimum value in this work since it could provide the highest EO yield, the highest EO selectivity, and the lowest power consumptions.

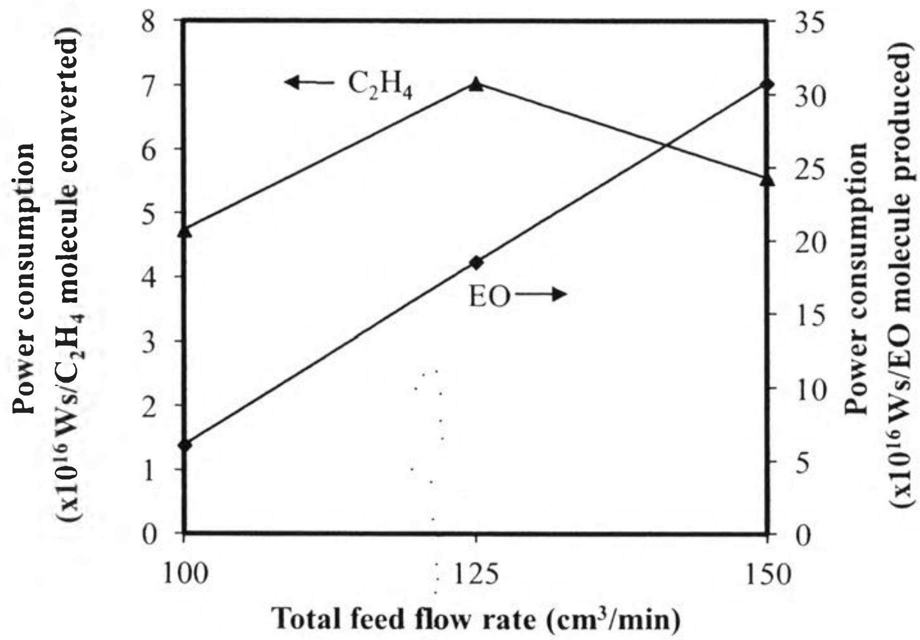

Figure 4.17 Power consumptions as a function as a function of total feed flow rate (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and gap distance between pin and plate electrodes = 1 cm).

4.6 Effect of Gap Distance between Pin and Plate Electrodes

To invest the effect of gap distance between pin and plate electrodes, the experiments were performed under the best conditions achieve above: a gap distance between plate electrode and C_2H_4 feed position of 0.2 cm, an O_2/C_2H_4 feed molar ratio of 0.5:1, an applied voltage of 18 kV, an input frequency of 500 Hz, and a total feed flow rate of 100 cm^3/min. The gap distance between pin and plate electrodes was varied in the range of 0.8–1.2 cm since a large amount of coke filaments was found to deposit on the electrode surfaces at a gap distance between pin and plate electrodes lower than 0.8 cm, and the generated plasma became unfavorably non-uniform at a gap distance between pin and plate electrodes higher than 1.2 cm.

4.6.1 Effect of Gap Distance between Pin and Plate Electrodes on Ethylene and Oxygen Conversions and Ethylene Oxide Yield

The effect of gap distance between pin and plate electrodes on the C_2H_4 and O_2 conversions and EO yield is illustrated on Figure 4.18. The C_2H_4 conversion tended to remain almost unchanged. In contrast, the O_2 conversion tended to increase with increasing gap distance between pin and plate electrodes. Even though the generated current decreased with increasing gap distance between pin and plate electrodes, as shown in Figure 4.19, the residence time of gases and active species in the plasma zone might more dominantly affect the O_2 conversion. However, the EO yield reached the maximum at a gap distance between pin and plate electrodes of 1 cm, and then it decreased with further increasing gap distance between pin and plate electrodes higher than 1 cm possibly because the residence time is simply increased, leading to higher probability of electrons reacting with the primary products and O_2 molecules to provide a variety of by-products.

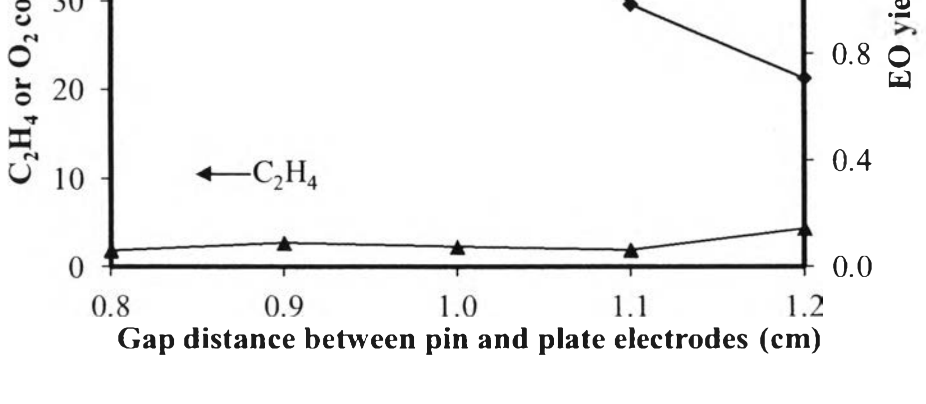

Figure 4.18 C_2H_4 and O_2 conversions and EO yield as a function of gap distance between pin and plate electrodes (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and total feed flow rate = 100 cm^3/min).

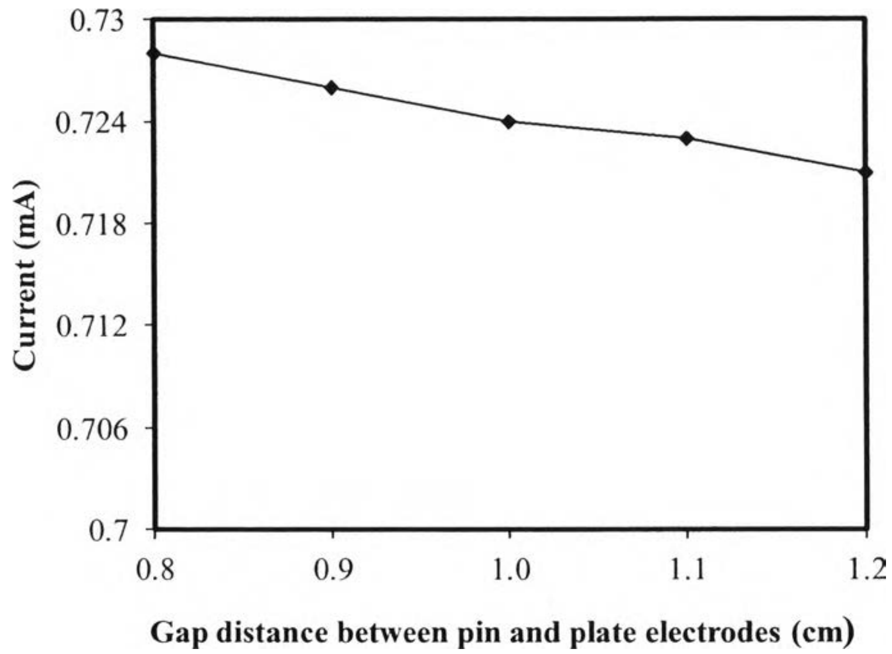

Figure 4.19 Generated current as a function of gap distance between pin and plate electrodes (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and total feed flow rate = 100 cm^3/min).

4.6.2 Effect of Gap Distance between Pin and Plate Electrodes on Product Selectivities

The effect of gap distance between pin and plate electrodes on the selectivities for EO, CO, H_2, CH_4, C_2H_2, and C_3H_8 is shown in Figure 4.20. The EO selectivity tended to remain almost constant in the range of gap distance between pin and plate electrodes between 0.8 and 1.0 cm and then sharply decreased with further increasing gap distance between pin and plate electrodes. Hence, a higher gap distance between pin and plate electrodes led to a lower opportunity of ethylene epoxidation. The selectivities for H_2, CH_4, C_2H_2, and C_3H_8 tended to only slightly change with increasing gap distance between pin and plate electrodes, but the CO selectivity significantly increased with increasing gap distance between pin and plate electrodes, which corresponded well to the result of increased O_2 conversion. These results suggest that the combustion was likely to occur at a too high gap distance between pin and plate electrodes.

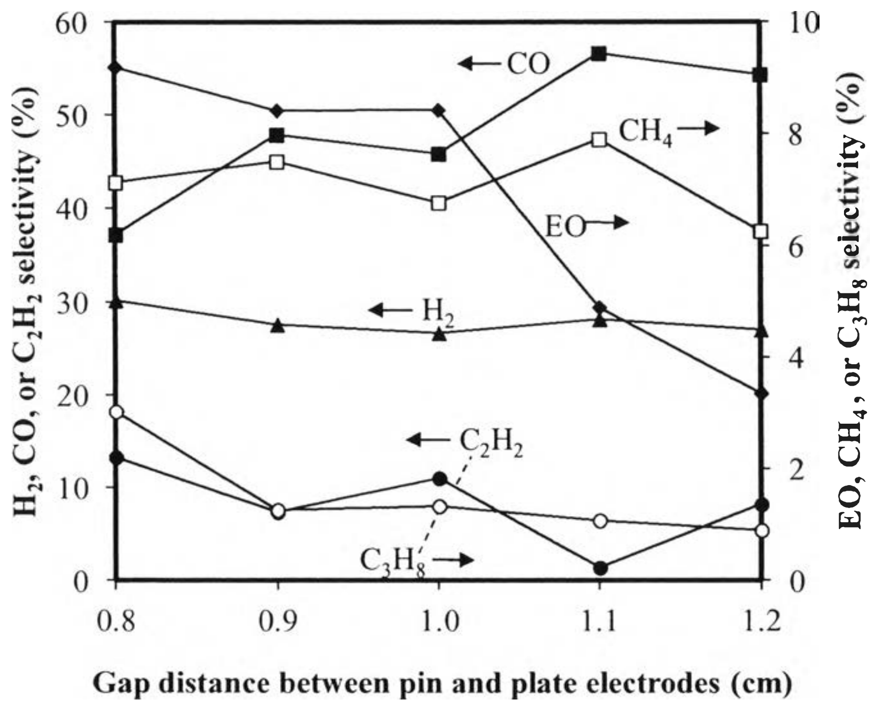

Figure 4.20 Product selectivities as a function of gap distance between pin and plate electrodes (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and total feed flow rate = 100 cm^3/min).

4.6.3 Effect of Gap Distance between Pin and Plate Electrodes on Power Consumptions

The effect of gap distance between pin and plate electrodes on the power consumptions is shown in Figure 4.21. The power consumption per molecule of converted C_2H_4 tended to slightly vary with increasing gap distance between pin and plate electrodes in the range of 0.8–1.1 cm and then rapidly decreased with further increasing gap distance between pin and plate electrodes to 1.2 cm, whereas the power consumption per molecule of produced EO was almost unchanged at the gap distance between pin and plate electrodes in the range of 0.8–1.0 cm and then sharply increased with further increasing gap distance between pin and plate electrodes. A possible reason is that a higher gap distance between pin and plate electrodes caused a higher probability of secondary reactions due to an increased residence time, which unavoidably consumed some power. Therefore, the gap distance between pin and plate electrodes of 1 cm was considered to be the optimum value because it provided the highest EO yield, the highest EO selectivity, and the comparatively low power consumption per molecule of produced EO.

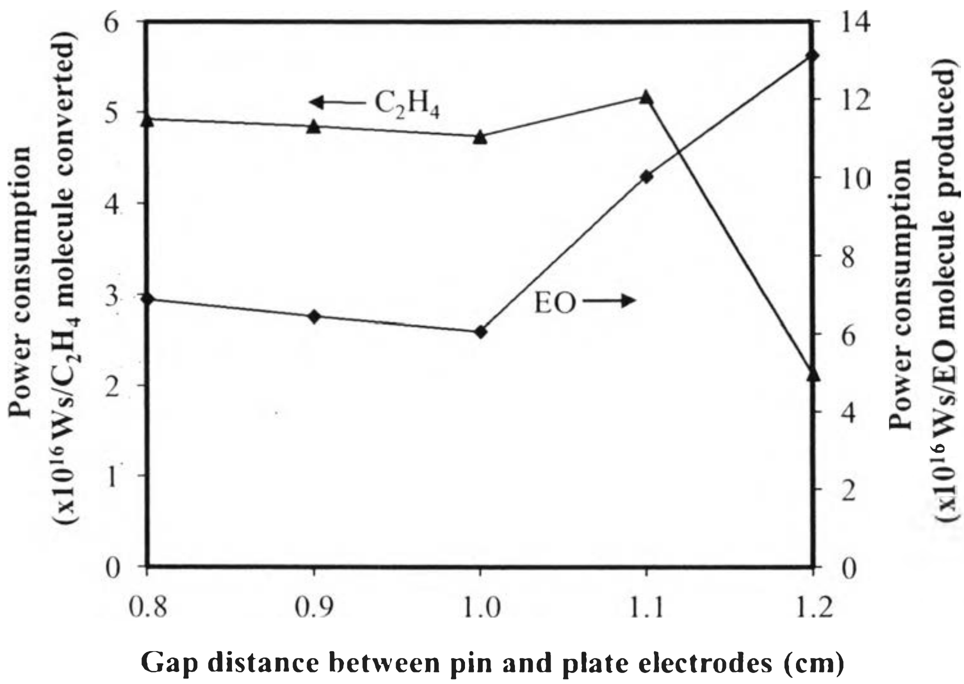

Figure 4.21 Power consumptions as a function of gap distance between pin and plate electrodes (distance between plate electrode and C_2H_4 feed position = 0.2 cm, O_2/C_2H_4 feed molar ratio = 0.5:1, applied voltage = 18 kV, input frequency = 500 Hz, and total feed flow rate = 100 cm^3/min).