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APPENDICES

Appendix A Assumptions, Definitions, and Calculations

In this work, the following assumptions were made:

1. All the gaseous behaviors obey the ideal gas law
2. The change in the system, pressure is very small and negligible.
3. The pressure in the system equals the atmospheric pressure (1 atm)

The total molar flow rate of the gaseous stream can be determined from the following equation:

$$N = q \times (P/RT) \quad (\text{B.1})$$

where

q = total volumetric flow rate

P = total pressure of the system

R = gas constant (82.051 atm·mL·mol⁻¹·K⁻¹)

T = absolute ambient temperature (K)

The molar flow rate of each component can be obtained by multiplying its fraction derived from the gas chromatography analysis by the total molar flow rate.

The conversion is defined as:

$$\% \text{ Conversion} = \frac{\text{Mole reactant in} - \text{Mole reactant out}}{\text{Mole reactant in}} \times 100 \quad (\text{B.2})$$

The first selectivity is defined as:

$$\% \text{ Selectivity} = \frac{P \times \text{Mole of } C_P \text{ produced}}{R \times \text{Mole of } C_R \text{ converted}} \times 100 \quad (\text{B.3})$$

where

P = number of carbon atom in product

R = number of carbon atom in reactant

C_P = product that has carbon P atom

C_R = product that has carbon R atom

The second selectivity is defined as:

$$\% \text{ Selectivity of H}_2 = \frac{\text{Molar flow rate of H}_2 \text{ produced}}{\text{Rate of H reacted}} \times 100 \quad (\text{B.4})$$

To determine the energy efficiency of gliding arc discharge system, the specific energy consumption was calculated in a unit of electron-volt per molecule of converted carbon (eV/m_c) from the following equation:

$$\text{Specific energy consumption} = \frac{P \times 60}{1.602 \times 10^{-19} \times \tilde{N} \times M_C} \text{ eV/molecule of reactants converted} \quad (\text{B.5})$$

where

P = Power (W)

\tilde{N} = Avogadro's number = 6.02×10^{23} molecule·g-mole⁻¹

M_C = Rate of reactants in feed gas converted (g-mole·min⁻¹)

1 eV = 1.602×10^{-19} W

Appendix B Experimental data

Table B.1 Effect of feed flow rate at 300 Hz, 15,500 V, and a gap distance of 0.6 cm

Flow Rate (mL/min)	Stage (s)	% Conversion		% Selectivity				
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
50	1	11.51	3.23	50.12	14.56	20.98	23.36	15.62
	2	17.56	4.28	57.47	18.23	24.82	27.13	15.44
	3	23.47	5.39	61.04	20.06	26.28	28.68	13.57
	4	28.55	6.33	65.55	21.84	27.96	29.51	11.75
100	1	8.41	2.83	47.72	12.09	18.69	18.79	12.97
	2	12.94	3.86	52.37	14.88	21.81	22.68	14.21
	3	17.25	4.93	54.21	16.34	23.06	23.93	13.55
	4	21.16	5.86	55.37	17.34	23.50	24.97	12.72
150	1	6.26	2.26	43.62	12.27	15.62	16.91	16.04
	2	10.33	3.65	50.17	14.23	20.59	20.58	14.95
	3	13.98	4.55	52.56	14.50	22.28	22.86	14.16
	4	17.26	5.28	53.68	15.63	23.05	23.25	13.42
200	1	6.14	2.14	54.56	12.94	20.76	20.39	14.15
	2	10.30	3.51	53.06	13.87	21.32	21.22	13.98
	3	14.77	4.51	55.01	15.18	23.48	22.76	13.40
	4	15.67	4.56	55.92	15.29	27.83	22.33	12.73

Table B.2 Effect of feed flow rate on effluent gas concentration at 300 Hz, 15,500 V, and a gap distance 0.6 cm

Flow Rate (mL/min)	Stage (s)	% Concentration						
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
50	1	60.68	26.14	7.91	1.28	0.92	1.02	0.69
	2	53.46	24.46	13.09	2.28	1.55	1.69	0.96
	3	47.30	23.04	17.72	3.18	2.08	2.27	1.07
	4	42.20	21.80	22.11	4.00	2.56	2.71	1.08
100	1	62.69	29.26	5.50	0.80	0.62	0.62	0.43
	2	57.76	28.06	8.99	1.45	1.06	1.10	0.69
	3	53.30	26.94	12.05	2.04	1.44	1.50	0.85
	4	49.72	26.11	14.77	2.60	1.76	1.87	0.95
150	1	65.93	29.07	3.84	0.62	0.40	0.43	0.41
	2	61.51	27.95	7.11	1.16	0.84	0.84	0.61
	3	57.56	27.01	9.84	1.54	1.19	1.22	0.75
	4	54.26	26.27	12.15	2.00	1.47	1.49	0.86
200	1	64.28	29.64	4.58	0.63	0.50	0.49	0.34
	2	60.42	28.75	7.36	1.11	0.85	0.85	0.56
	3	55.65	27.58	10.61	1.66	1.29	1.25	0.73
	4	54.95	27.51	11.42	1.76	1.60	1.29	0.73

Table B.3 Effect of feed flow rate on power consumption at 300 Hz, 15,500 V, and a gap distance 0.6 cm

Flow Rate (mL/min)	Stage (s)	Power Consumption (eV/molecule of reactants converted)
50	1	34.12
	2	35.11
	3	37.48
	4	40.04
100	1	27.04
	2	28.25
	3	28.57
	4	31.17
150	1	25.79
	2	23.49
	3	23.39
	4	23.50
200	1	30.76
	2	26.19
	3	25.01
	4	24.63

Table B.4 Effect of residence time at 300 Hz, 15,500 V, and a gap distance 0.6 cm

Residence Time (s)	Stage (s)	% Conversion		% Selectivity				
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
0.8276	1	6.14	2.14	54.56	12.94	20.76	20.39	14.15
	2	10.30	3.51	53.06	13.87	21.32	21.22	13.98
	3	14.77	4.51	55.01	15.18	23.48	22.76	13.40
	4	15.67	4.56	55.92	15.29	27.83	22.33	12.73
1.1035	1	6.26	2.26	43.62	12.27	15.62	16.91	16.04
	2	10.33	3.65	50.17	14.23	20.59	20.58	14.95
	3	13.98	4.55	52.56	14.50	22.28	22.86	14.16
	4	17.26	5.28	53.68	15.63	23.05	23.25	13.42
1.6552	1	8.41	2.83	47.72	12.09	18.69	18.79	12.97
	2	12.94	3.86	52.37	14.88	21.81	22.68	14.21
	3	17.25	4.93	54.21	16.34	23.06	23.93	13.55
	4	21.16	5.86	55.37	17.34	23.50	24.97	12.72
3.3104	1	11.51	3.23	50.12	14.56	20.98	23.36	15.62
	2	17.56	4.28	57.47	18.23	24.82	27.13	15.44
	3	23.47	5.39	61.04	20.06	26.28	28.68	13.57
	4	28.55	6.33	65.55	21.84	27.96	29.51	11.75

Table B.5 Effect of residence time on effluent gas concentration at 300 Hz, 15,500 V, and a gap distance 0.6 cm

Residence Time (s)	Stage (s)	% Concentration						
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
0.8276	1	64.28	29.64	4.58	0.63	0.50	0.49	0.34
	2	60.42	28.75	7.36	1.11	0.85	0.85	0.56
	3	55.65	27.58	10.61	1.66	1.29	1.25	0.73
	4	54.95	27.51	11.42	1.76	1.60	1.29	0.73
1.1035	1	65.93	29.07	3.84	0.62	0.40	0.43	0.41
	2	61.51	27.95	7.11	1.16	0.84	0.84	0.61
	3	57.56	27.01	9.84	1.54	1.19	1.22	0.75
	4	54.26	26.27	12.15	2.00	1.47	1.49	0.86
1.6552	1	62.69	29.26	5.50	0.80	0.62	0.62	0.43
	2	57.76	28.06	8.99	1.45	1.06	1.10	0.69
	3	53.30	26.94	12.05	2.04	1.44	1.50	0.85
	4	49.72	26.11	14.77	2.60	1.76	1.87	0.95
3.3104	1	60.68	26.14	7.91	1.28	0.92	1.02	0.69
	2	53.46	24.46	13.09	2.28	1.55	1.69	0.96
	3	47.30	23.04	17.72	3.18	2.08	2.27	1.07
	4	42.20	21.80	22.11	4.00	2.56	2.71	1.08

Table B.6 Effect of residence time on power consumption at 300 Hz, 15,500 V, and a gap distance 0.6 cm

Residence Time (s)	Stage (s)	Power Consumption (eV/molecule of reactants converted)
0.8276	1	30.76
	2	26.19
	3	25.01
	4	24.63
1.1035	1	25.79
	2	23.49
	3	23.39
	4	23.50
1.6552	1	27.04
	2	28.25
	3	28.57
	4	31.17
3.3104	1	34.12
	2	35.11
	3	37.48
	4	40.04

Table B.7 Effect of frequency at 150 mL/min, 15,500 V, and a gap distance 0.6 cm

Frequency (Hz)	Stage (s)	% Conversion		% Selectivity				
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
300	1	6.26	2.26	43.62	12.27	15.62	16.91	16.04
	2	10.33	3.65	50.17	14.23	20.59	20.58	14.95
	3	13.98	4.55	52.56	14.50	22.28	22.86	14.16
	4	17.26	5.28	53.68	15.63	23.05	23.25	13.42
400	1	6.11	2.25	43.86	12.33	16.83	17.59	14.19
	2	9.61	3.40	48.44	15.07	19.74	20.65	16.16
	3	12.87	4.44	49.83	16.62	21.35	21.83	16.11
	4	15.78	5.23	51.93	17.90	22.54	22.54	15.84
500	1	5.78	2.15	42.18	13.31	16.78	16.38	12.90
	2	8.77	3.40	50.23	17.40	20.32	19.77	16.23
	3	11.86	4.44	52.75	19.20	23.14	21.12	16.05
	4	15.38	5.20	55.15	19.86	25.97	21.52	14.71
600	1	5.20	2.06	42.12	15.14	15.82	15.30	13.66
	2	8.04	3.25	49.04	19.65	19.90	18.70	16.82
	3	10.84	4.42	52.68	21.87	22.15	19.74	17.41
	4	13.53	5.18	55.49	23.89	24.32	20.53	17.56
700	1	4.66	2.01	36.33	14.86	12.66	12.42	13.61
	2	7.24	3.12	43.73	19.01	16.14	15.25	16.36
	3	9.40	4.41	48.23	21.66	18.82	16.79	17.43
	4	11.74	5.11	52.84	23.24	22.88	18.02	16.54

Table B.8 Effect of frequency on effluent gas concentration at 150 mL/min, 15,500 V, and a gap distance 0.6 cm

Frequency (Hz)	Stage (s)	% Concentration						
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
300	1	65.93	29.07	3.84	0.62	0.40	0.43	0.41
	2	61.51	27.95	7.11	1.16	0.84	0.84	0.61
	3	57.56	27.01	9.84	1.54	1.19	1.22	0.75
	4	54.26	26.27	12.15	2.00	1.47	1.49	0.86
400	1	66.13	29.13	3.78	0.61	0.42	0.44	0.35
	2	62.34	28.19	6.43	1.15	0.75	0.79	0.62
	3	58.84	27.30	8.66	1.66	1.06	1.09	0.80
	4	55.75	26.54	10.85	2.13	1.34	1.34	0.94
500	1	66.84	29.30	3.46	0.63	0.40	0.39	0.31
	2	63.25	28.27	6.11	1.23	0.72	0.70	0.57
	3	59.59	27.27	8.46	1.78	1.08	0.98	0.75
	4	55.67	26.32	11.16	2.30	1.50	1.24	0.85
600	1	66.52	28.95	3.07	0.64	0.34	0.33	0.29
	2	63.23	28.03	5.42	1.27	0.64	0.61	0.54
	3	59.99	27.09	7.69	1.87	0.95	0.84	0.74
	4	56.66	26.18	9.84	2.46	1.25	1.06	0.90
700	1	67.52	29.12	2.40	0.58	0.25	0.24	0.27
	2	64.75	28.37	4.42	1.13	0.48	0.46	0.49
	3	62.13	27.51	6.22	1.67	0.73	0.65	0.67
	4	59.05	26.64	8.30	2.16	1.06	0.84	0.77

Table B.9 Effect of frequency on current and power consumption at 150 mL/min, 15,500 V, and a gap distance 0.6 cm

Frequency (Hz)	Stage (s)	Current (Amp)	Power Consumption (eV/molecule of reactants converted)
300	1	0.19	25.79
	2	0.38	23.49
	3	0.57	23.39
	4	0.75	23.50
400	1	0.16	21.43
	2	0.31	20.88
	3	0.45	20.53
	4	0.60	20.44
500	1	0.14	19.33
	2	0.27	18.98
	3	0.45	18.80
	4	0.60	18.79
600	1	0.13	23.82
	2	0.25	23.05
	3	0.39	22.19
	4	0.55	22.08
700	1	0.13	29.43
	2	0.23	27.55
	3	0.38	26.82
	4	0.47	26.50

Table B.10 Effect of voltage at 300 Hz, 150 mL/min, and a gap distance 0.6 cm

Voltage (V)	Stage (s)	% Conversion		% Selectivity				
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
14000	1	5.96	2.20	45.54	11.88	16.88	18.31	14.63
	2	9.62	3.57	51.11	15.12	21.11	20.96	15.57
	3	12.87	4.51	52.96	16.52	22.39	22.66	15.91
	4	15.78	5.22	54.51	18.00	23.75	23.22	15.43
14750	1	6.06	2.22	46.77	11.48	17.35	18.15	13.78
	2	9.97	3.61	51.90	14.35	21.78	21.20	14.56
	3	13.57	4.52	53.00	15.45	22.47	23.86	14.78
	4	16.40	5.26	53.77	16.75	22.93	23.88	14.80
15500	1	6.26	2.26	43.62	12.27	15.62	16.91	16.04
	2	10.33	3.65	50.17	14.23	20.59	20.58	14.95
	3	13.98	4.55	52.56	14.50	22.28	22.86	14.16
	4	17.26	5.28	53.68	15.63	23.05	23.25	13.42
16250	1	7.61	2.38	47.83	10.66	19.70	17.79	11.32
	2	12.34	3.91	50.89	12.63	22.27	20.31	12.08
	3	15.92	4.61	54.14	14.14	24.14	22.35	12.13
	4	20.24	5.54	55.98	16.45	24.16	24.85	12.58
17000	1	7.64	2.52	53.75	11.39	22.38	20.04	12.12
	2	12.36	5.31	56.44	12.87	24.62	20.63	11.32
	3	17.37	5.35	55.98	13.76	25.74	21.23	10.61
	4	21.48	5.72	57.15	14.93	26.45	23.03	10.27

Table B.11 Effect of voltage on effluent gas concentration at 300 Hz, 150 mL/min, and a gap distance 0.6 cm

Voltage (V)	Stage (s)	% Concentration						
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
14000	1	65.91	28.95	3.80	0.57	0.41	0.44	0.35
	2	61.85	27.87	6.73	1.15	0.80	0.80	0.59
	3	58.27	26.97	9.11	1.63	1.11	1.12	0.79
	4	55.16	26.21	11.27	2.12	1.40	1.37	0.91
14750	1	66.34	29.06	4.00	0.57	0.43	0.45	0.34
	2	62.06	27.96	7.14	1.14	0.86	0.84	0.58
	3	58.24	27.07	9.69	1.61	1.17	1.19	0.77
	4	55.29	26.37	11.66	2.06	1.41	1.47	0.91
15500	1	65.93	29.07	3.84	0.62	0.40	0.43	0.41
	2	61.51	27.95	7.11	1.16	0.84	0.84	0.61
	3	57.56	27.01	9.84	1.54	1.19	1.22	0.75
	4	54.26	26.27	12.15	2.00	1.47	1.49	0.86
16250	1	65.03	28.98	5.12	0.65	0.60	0.54	0.34
	2	60.11	27.79	8.62	1.21	1.07	0.97	0.58
	3	55.98	26.79	11.47	1.68	1.44	1.33	0.72
	4	51.15	25.55	14.53	2.38	1.75	1.80	0.91
17000	1	64.15	28.58	5.70	0.69	0.68	0.61	0.37
	2	59.74	27.25	9.51	1.28	1.22	1.03	0.56
	3	54.21	26.22	12.76	1.77	1.66	1.37	0.68
	4	49.90	25.29	15.60	2.27	2.01	1.75	0.78

Table B.12 Effect of voltage on current and power consumption at 300 Hz, 150 mL/min, and a gap distance 0.6 cm

Voltage (V)	Stage (s)	Current (Amp)	Power Consumption (eV/molecule of reactants converted)
14000	1	0.17	25.82
	2	0.34	24.93
	3	0.50	24.56
	4	0.67	24.12
14750	1	0.18	28.87
	2	0.37	26.96
	3	0.53	26.08
	4	0.71	25.55
15500	1	0.19	25.79
	2	0.38	23.49
	3	0.57	23.39
	4	0.75	23.50
16250	1	0.21	24.84
	2	0.41	23.19
	3	0.61	23.13
	4	0.79	21.57
17000	1	0.22	23.79
	2	0.43	21.03
	3	0.63	20.73
	4	0.83	20.61

Table B.13 Effect of gap distance at 150 mL/min, 300 Hz and 17,000 V

Gap Distance (cm)	Stage (s)	% Conversion		% Selectivity				
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
0.6	1	7.64	2.52	53.75	11.39	22.38	20.04	12.12
	2	12.36	5.31	56.44	12.87	24.62	20.63	11.32
	3	17.37	5.35	55.98	13.76	25.74	21.23	10.61
	4	21.48	5.72	57.15	14.93	26.45	23.03	10.27
0.8	1	7.98	2.72	50.74	11.10	20.62	18.83	11.71
	2	12.70	5.46	45.82	11.41	17.67	18.38	11.98
	3	18.90	6.95	50.63	13.66	21.27	19.96	10.67
	4	22.36	7.73	52.64	14.93	22.33	21.26	10.26

Table B.14 Effect of gap distance on effluent gas concentration at 150 mL/min, 300 Hz and 17,000 V

Gap Distance (cm)	Stage (s)	% Concentration						
		CH ₄	CO ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
0.6	1	64.15	28.58	5.70	0.69	0.68	0.61	0.37
	2	59.74	27.25	9.51	1.28	1.22	1.03	0.56
	3	54.21	26.22	12.76	1.77	1.66	1.37	0.68
	4	49.90	25.29	15.60	2.27	2.01	1.75	0.78
0.8	1	63.80	28.85	5.62	0.70	0.65	0.60	0.37
	2	59.40	27.51	7.92	1.17	0.90	0.94	0.61
	3	53.68	26.34	12.66	1.98	1.54	1.44	0.77
	4	50.23	25.53	15.23	2.48	1.85	1.76	0.85

Table B.15 Effect of gap distance on power consumption at 150 mL/min, 300 Hz and 17,000 V

Gap Distance (cm)	Stage (s)	Power Consumption (eV/molecule of reactants converted)
0.6	1	23.79
	2	21.03
	3	20.73
	4	20.61
0.8	1	27.83
	2	23.21
	3	21.94
	4	21.52

Table B.16 Effect of O₂ concentration at 150 mL/min, 300 Hz, 17,000 V, and a gap distance 0.6 cm

O ₂ /CH ₄ ratio	Stage (s)	% Conversion			% Selectivity				
		CH ₄	CO ₂	O ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
0.2/1	1	37.94	11.95	46.75	54.95	34.34	34.79	4.36	0.00
	2	58.06	24.88	70.78	54.08	38.86	33.65	3.46	0.00
	3	72.04	37.63	84.85	49.42	40.70	32.20	2.78	0.00
	4	79.40	47.28	91.54	55.40	42.89	29.15	2.51	0.00
0.3/1	1	50.01	25.03	57.87	41.71	35.30	21.55	2.98	0.00
	2	70.55	39.04	82.14	45.50	43.23	22.48	2.59	0.00
	3	76.58	42.87	88.37	42.21	45.87	23.78	2.53	0.00
	4	81.37	49.25	92.39	49.50	49.96	20.67	2.32	0.00
0.4/1	1	38.09	11.59	44.54	50.39	51.67	24.42	4.56	0.00
	2	59.58	20.82	70.96	50.77	59.94	23.67	3.82	0.00
	3	77.00	39.61	89.24	43.03	60.69	21.34	2.74	0.00
	4	83.06	47.97	93.90	51.64	63.43	17.32	2.45	0.00

Table B.17 Effect of O₂ concentration on effluent gas concentration at 150 mL/min, 300 Hz, 17,000 V, and a gap distance 0.6 cm

O ₂ /CH ₄ ratio	Stage (s)	% Concentration							
		CH ₄	CO ₂	O ₂	H ₂	CO	C ₂ H ₂	C ₂ H ₄	C ₂ H ₆
0.2/1	1	12.75	7.26	1.93	8.56	3.01	1.53	0.19	0.00
	2	8.56	6.15	1.05	12.82	5.40	2.34	0.24	0.00
	3	5.74	5.14	0.55	15.85	7.29	2.88	0.25	0.00
	4	4.17	4.28	0.30	17.81	8.54	3.16	0.25	0.00
0.3/1	1	11.26	6.89	2.70	9.39	4.79	1.46	0.20	0.00
	2	6.50	5.50	1.12	14.17	8.27	2.15	0.25	0.00
	3	5.06	5.04	0.71	15.86	9.32	2.42	0.26	0.00
	4	3.91	4.35	0.45	16.92	10.65	2.51	0.25	0.00
0.4/1	1	12.54	7.17	4.35	7.77	4.47	1.06	0.20	0.00
	2	8.01	6.28	2.23	11.99	8.07	1.59	0.26	0.00
	3	4.58	4.81	0.82	15.61	11.22	1.97	0.25	0.00
	4	3.32	4.09	0.46	16.83	12.73	2.07	0.25	0.00

Table B.18 Effect of O₂ concentration on power consumption at 150 mL/min, 300 Hz, 17,000 V, and a gap distance 0.6 cm

O ₂ /CH ₄ ratio	Stage (s)	Power Consumption (eV/molecule of reactants converted)
0.2/1	1	14.86
	2	14.11
	3	13.91
	4	15.29
0.3/1	1	8.45
	2	9.05
	3	10.88
	4	12.69
0.4/1	1	11.47
	2	11.85
	3	11.19
	4	12.41

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