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APPENDICES

Appendix A Experimental data

Table A1 Effect of steam content on reactant conversions and product yields for the reforming of natural gas with steam (total feed flow rate, 100 cm^3/min; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Steam content (mol%)	Reactant conversion (%)				Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	C_2	CO
0	11.79	22.69	29.81	7.47	29.07	25.71	2.14
10	15.39	25.86	31.57	9.46	39.04	23.10	2.66
15	12.07	24.85	33.15	8.38	34.62	23.66	2.91
20	10.16	22.41	34.92	7.19	34.60	23.85	2.94
30	7.66	20.70	27.86	4.41	27.35	20.57	2.38

Table A2 Effect of steam content on concentrations of outlet gas for the reforming of natural gas with steam (total feed flow rate, 100 cm^3/min; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Steam content (mol%)	Concentration of outlet gas (mol%)								
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
0	61.69	3.95	3.48	19.46	13.38	0.55	0.61	2.67	0.38
10	61.34	3.79	3.39	19.04	17.45	0.66	0.69	2.18	0.60
15	64.68	3.84	3.31	12.27	13.10	0.64	0.46	2.15	0.37
20	65.14	3.97	3.22	19.52	12.87	0.63	0.44	2.18	0.38
30	66.95	4.06	3.57	20.10	9.63	0.49	0.31	1.85	0.28

Table A3 Effect of steam content on product selectivities for the reforming of natural gas with steam (total feed flow rate, 100 cm^3/min; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Steam content (mol%)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
0	43.12	2.86	6.40	27.93	8.01
10	53.60	3.23	6.77	21.30	11.71
15	50.32	3.77	5.45	25.21	8.70
20	49.97	3.93	5.34	26.60	9.07
30	48.65	2.86	4.95	28.98	8.67

Table A4 Effect of steam content on product molar ratios for the reforming of natural gas with steam (total feed flow rate, 100 cm^3/min; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Steam content (mol%)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
0	19.37	30.54	5.22	5.85
10	24.41	21.83	5.00	4.36
15	26.34	25.15	7.99	3.14
20	20.36	28.18	6.09	4.62
30	20.01	29.45	5.91	4.98

Table A5 Effect of steam content on power consumptions for the reforming of natural gas with steam (total feed flow rate, 100 cm^3/min; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm) (E_C: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Steam content (mol%)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
0	3.42	3.27
10	2.12	1.94
15	2.43	2.32
20	2.58	2.36
30	3.40	3.15

Table A6 Effect of total feed flow rate on reactant conversions and product yields, for the reforming of natural gas with steam (steam content, 10 mol%; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Total feed flow rate (cm^3/min)	Reactant conversion (%)				Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	C_2	CO
75	16.27	26.32	29.76	9.17	29.65	23.77	1.59
100	15.40	25.86	31.57	9.46	39.04	23.10	2.66
125	13.09	23.35	30.29	4.74	29.91	23.85	1.47
150	9.92	20.88	28.50	2.73	24.55	24.16	1.24

Table A7 Effect of total feed flow rate on concentrations of outlet gas for the reforming of natural gas with steam (steam content, 10 mol%; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Total feed flow rate (cm^3/min)	Concentration of outlet gas (mol%)								
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
75	59.91	3.72	3.43	18.85	13.56	0.40	0.37	2.63	0.41
100	61.34	3.79	3.89	19.04	17.45	0.66	0.69	2.18	0.60
125	62.18	3.87	3.41	19.77	12.64	0.35	0.35	2.51	0.43
150	64.46	3.99	3.49	20.19	9.49	0.28	0.26	2.45	0.34

Table A8 Effect of total feed flow rate on product selectivities, and for the reforming of natural gas with steam (steam content, 10 mol%; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Total feed flow rate (cm^3/min)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
75	40.99	1.95	3.62	25.55	8.04
100	53.60	3.23	6.77	21.30	11.71
125	44.82	2.05	4.10	29.27	10.10
150	41.41	2.00	3.76	35.19	9.68

Table A9 Effect of total feed flow rate on product molar ratios for the reforming of natural gas with steam (steam content, 10 mol%; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Total feed flow rate (cm^3/min)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
75	33.88	36.48	5.16	7.07
100	26.34	25.15	7.99	3.15
125	35.93	35.95	5.03	7.14
150	34.05	36.19	3.88	9.36

Table A10 Effect of total feed flow rate on power consumptions for the reforming of natural gas with steam (steam content, 10 mol%; input voltage, 17.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm) (E_C: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Total feed flow rate (cm^3/min)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
75	2.36	2.84
100	2.12	1.95
125	2.72	2.80
150	3.49	3.72

Table A11 Effect of input voltage on reactant conversions and product yields for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Input voltage (kV)	Reactant conversion (%)				Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	C_2	CO
12.5	10.66	16.64	29.77	1.44	37.21	17.33	2.36
13.5	12.11	19.08	30.02	4.67	40.25	18.05	3.13
14.5	13.53	19.45	25.90	6.28	37.49	17.45	2.44
15.5	12.74	20.45	30.48	5.20	39.69	20.05	2.82
16.5	16.34	27.16	39.30	8.37	42.60	23.46	3.43
17.5	15.40	25.86	31.57	9.46	39.04	23.10	2.66
18.5	15.55	28.27	38.79	8.57	42.97	24.77	2.38

Table A12 Effect of input voltage on concentrations of outlet gas for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Input voltage (kV)	Concentration of outlet gas (mol%)								
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
12.5	64.25	4.26	3.62	19.27	15.66	0.56	0.46	1.65	0.33
13.5	61.90	4.03	3.52	18.97	17.07	0.76	0.61	1.57	0.28
14.5	61.23	4.02	3.66	19.03	17.31	0.62	0.66	1.56	0.25
15.5	62.00	3.96	3.40	19.07	16.92	0.68	0.60	1.82	0.30
16.5	60.18	3.72	3.06	18.56	18.32	0.83	0.71	2.14	0.36
17.5	61.34	3.79	3.39	19.04	17.44	0.66	0.69	2.18	0.60
18.5	61.25	3.67	3.06	18.74	18.01	0.57	0.68	2.27	0.36

Table A13 Effect of input voltage on product selectivities for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Input voltage (kV)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
12.5	65.20	4.04	6.48	23.15	9.22
13.5	65.75	7.55	7.68	19.71	6.98
14.5	63.68	3.75	7.95	18.82	6.00
15.5	62.34	4.10	7.17	21.93	7.23
16.5	51.46	3.76	6.39	19.33	6.43
17.5	53.60	3.23	6.77	21.30	11.7
18.5	52.01	2.61	6.31	20.85	6.69

Table A14 Effect of input voltage on product molar ratios for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Input voltage (kV)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
12.5	27.18	33.93	9.46	3.57
13.5	22.58	27.95	10.89	2.56
14.5	27.78	26.17	11.05	2.37
15.5	24.84	28.36	9.28	3.06
16.5	21.96	25.83	8.55	3.02
17.5	26.34	21.15	7.99	3.14
18.5	31.68	26.27	7.94	3.30

Table A15 Effect of input voltage on power consumptions for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm) (E_C: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input voltage (kV)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
12.5	2.29	1.51
13.5	2.26	1.58
14.5	2.31	1.75
15.5	2.46	1.83
16.5	2.38	1.86
17.5	2.12	1.95
18.5	1.94	1.77

Table A16 Effect of input frequency on reactant conversions and product yields for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage 13.5 kV; and electrode gap distance, 6 mm).

Input frequency (Hz)	Reactant conversion (%)				Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	C_2	CO
300	12.12	19.08	30.02	4.67	40.25	18.05	3.13
400	11.67	15.36	25.05	6.20	35.29	15.33	3.07
500	8.30	9.83	17.87	5.20	32.11	10.61	2.98
600	6.30	4.90	8.04	3.29	16.11	6.94	1.93

Table A17 Effect of input frequency concentrations of outlet gas for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage 13.5 kV; and electrode gap distance, 6 mm).

Input frequency (Hz)	Concentration of outlet gas (mol%)								
	CH_4	C_2H_6	C_3H_8	CO_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
300	61.90	4.03	3.52	18.97	17.07	0.76	0.61	1.57	0.28
400	63.46	4.27	3.68	19.04	16.27	0.78	0.52	1.44	0.29
500	65.58	4.57	4.14	19.79	15.14	0.77	0.39	0.99	0.22
600	67.04	4.80	4.49	20.07	14.19	0.59	0.26	0.79	0.24

Table A18 Effect of input frequency on product selectivities for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage 13.5 kV; and electrode gap distance, 6 mm).

Input frequency (Hz)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
300	65.75	4.76	7.68	19.72	6.99
400	67.75	5.27	6.93	19.37	7.74
500	69.18	7.23	6.82	18.53	8.42
600	71.63	5.67	7.63	23.15	13.95

Table A19 Effect of input frequency on product molar ratios for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage 13.5 kV; and electrode gap distance, 6 mm).

Input frequency (Hz)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
300	22.57	27.95	10.89	2.57
400	20.72	31.50	11.27	2.79
500	19.53	39.10	15.24	2.57
600	16.13	36.19	11.94	3.03

Table A20 Effect of input frequency on power consumptions for the reforming of natural gas with steam (steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage 13.5 kV; and electrode gap distance, 6 mm) (E_C: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input frequency (Hz)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
300	2.26	1.58
400	2.86	2.05
500	3.61	2.01
600	6.05	3.72

Appendix B Experimental data

Table B1 Effects of HCs-to-O_2 feed molar ratio on reactant conversions and product yields under studied conditions: steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage, 13.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

HCs-to-O_2 feed molar ratio	Reactant conversion (%)					Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	C_2	CO
2/1	19.14	27.12	35.65	-0.66	29.41	59.29	21.10	46.43
3/1	16.32	25.63	35.92	2.47	28.52	57.37	23.29	35.98
4/1	15.09	21.50	30.26	4.69	23.98	46.04	18.48	19.42
6/1	9.38	16.06	28.16	4.46	19.66	44.85	20.59	11.22
9/1	9.37	14.43	23.73	4.16	18.27	41.35	16.82	8.49
without O_2	11.76	18.00	31.90	4.41	22.30	28.97	14.80	5.62

Table B2 Effects of HCs-to-O_2 feed molar ratio on concentrations of outlet gas under studied conditions: steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage, 13.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

HCs-to-O_2 feed molar ratio	Concentration of outlet gas (mol%)									
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
2/1	37.14	2.53	2.22	14.40	22.66	18.33	8.15	0.41	1.45	0.18
3/1	41.67	2.75	2.35	14.96	18.70	17.96	6.43	0.43	1.65	0.22
4/1	47.16	3.20	2.85	15.99	14.90	16.77	3.97	0.38	1.51	0.22
6/1	55.83	3.73	3.19	17.65	9.80	15.65	2.27	0.31	1.78	0.31
9/1	57.49	3.88	3.43	21.78	8.08	15.76	1.87	0.34	1.51	0.25
without O_2	59.01	3.88	4.49	18.27	4.76	16.36	1.62	0.38	1.74	3.26

Table B3 Effects of HCs-to-O_2 feed molar ratio on product selectivities under studied conditions: steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage, 13.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

HCs-to-O_2 feed molar ratio	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
2/1	72.38	57.14	5.71	20.26	5.04
3/1	73.68	44.73	6.00	22.99	6.20
4/1	68.88	27.15	5.25	20.58	6.08
6/1	83.67	19.33	5.30	30.16	10.41
9/1	86.99	16.42	5.99	26.56	8.67
without O_2	86.08	14.77	7.02	31.87	8.89

TableB4 Effects of HCs-to-O_2 feed molar ratio on product molar ratios under studied conditions: steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage, 13.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

HCs-to-O_2 feed molar ratio	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
2/1	2.25	45.03	12.68	3.55
3/1	2.79	41.67	10.88	3.83
4/1	4.22	43.62	11.13	3.91
6/1	6.87	50.10	8.81	5.69
9/1	8.42	46.11	10.41	4.43
without O_2	10.11	42.54	9.37	4.54

Table B5 Effects of HCs-to-O_2 feed molar ratio on power consumptions and coke formation under studied conditions: steam content, 10 mol%; total feed flow rate, 100 cm^3/min; input voltage, 13.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

HCs-to-O_2 feed molar ratio	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
2/1	2.65	1.57
3/1	3.28	1.97
4/1	3.13	2.11
6/1	4.12	2.26
9/1	4.10	2.24
without O_2	3.63	2.60

Table B6 Effects of input voltage on reactant conversions and product yields under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Voltage (kV)	Reactant conversion (%)					Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	C_2	CO
13.5	19.14	27.11	35.65	-0.65	29.41	59.29	21.10	46.43
14.5	22.28	31.22	39.42	-2.81	34.62	63.39	21.75	53.99
15.5	24.11	33.78	41.66	-3.84	38.43	66.44	22.46	60.71
16.5	26.92	37.90	46.41	-1.41	42.18	67.67	23.08	63.93
17.5	30.34	43.59	52.56	-2.84	47.35	73.93	24.88	75.74
18.5	31.33	43.50	51.45	-0.75	47.24	74.34	24.11	76.71
19.5	32.03	44.56	52.53	-1.57	48.05	74.78	24.32	78.71
20.5	33.47	46.92	55.02	0.38	51.45	77.67	25.00	83.71

Table B7 Effects of input voltage on concentrations of outlet gas under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Voltage (kV)	Concentration of outlet gas (mol%)									
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
13.5	37.14	2.53	2.22	14.41	22.66	18.33	8.15	0.41	1.45	0.18
14.5	35.41	2.34	2.03	14.17	21.10	19.63	9.50	0.48	1.44	0.17
15.5	34.27	2.23	1.92	14.40	20.14	20.48	10.62	0.52	1.44	0.17
16.5	33.53	2.14	1.83	14.16	19.06	21.26	11.36	0.57	1.49	0.17
17.5	31.80	1.93	1.61	14.26	17.03	22.97	13.34	0.66	1.53	0.17
18.5	31.22	1.92	1.62	14.19	17.18	23.42	13.59	0.72	1.41	0.16
19.5	30.86	1.88	1.59	14.31	17.06	23.54	13.95	0.74	1.41	0.16
20.5	30.11	1.79	1.49	14.11	15.95	24.30	14.71	0.79	1.41	0.16

Table B8 Effects of input voltage on product selectivities under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Voltage (kV)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
13.5	72.38	57.14	5.71	20.26	5.04
14.5	68.22	59.91	6.02	18.12	4.43
15.5	66.74	63.43	6.27	17.20	4.11
16.5	60.83	58.21	5.79	15.22	3.57
17.5	58.45	61.25	6.05	14.07	3.21
18.5	58.86	61.10	6.51	12.69	2.93
19.5	57.91	61.71	6.59	12.48	2.92
20.5	57.35	61.65	6.62	11.79	2.74

TableB9 Effects of input voltage on product molar ratios under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Voltage (kV)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
13.5	2.25	45.03	12.68	3.55
14.5	2.07	41.14	13.67	3.01
15.5	1.93	39.02	14.21	2.75
16.5	1.87	37.60	14.31	2.63
17.5	1.72	34.85	14.99	2.32
18.5	1.71	32.32	16.60	1.95
19.5	1.69	31.61	16.68	1.89
20.5	1.65	3.77	17.27	1.78

Table B10 Effects of input voltage on power consumptions and coke formation under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input frequency, 300 Hz; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Voltage (kV)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
13.5	2.65	1.57
14.5	1.99	1.22
15.5	2.05	1.29
16.5	2.08	1.47
17.5	2.01	1.46
18.5	2.08	1.54
19.5	2.05	1.53
20.5	2.07	1.58

Table B11 Effects of input frequency on reactant conversions and product yields, under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5kV; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Frequency (Hz)	Reactant conversion (%)					Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	C_2	CO
290	26.24	37.80	47.15	-2.35	41.72	69.42	24.76	66.80
300	22.28	31.22	39.42	-2.81	34.62	63.39	21.75	53.99
350	25.69	35.42	44.62	-0.82	38.23	65.56	23.09	60.70
400	21.72	29.65	39.45	-1.02	31.65	62.76	21.71	50.76
500	16.55	22.95	31.93	-0.48	24.74	59.53	18.71	41.52

Table B12 Effects of input frequency on concentrations of outlet gas under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5kV; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Frequency (Hz)	Concentration of outlet gas (mol%)									
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
290	33.58	2.11	1.77	14.31	18.78	21.26	11.61	0.57	1.58	0.19
300	35.41	2.34	2.03	14.17	21.10	19.63	9.50	0.48	1.44	0.18
350	34.01	2.20	1.85	13.96	20.01	20.53	10.73	0.57	1.47	0.18
400	35.65	2.39	2.02	13.95	22.13	19.40	8.89	0.49	1.42	0.19
500	37.96	2.61	2.26	13.84	24.34	18.03	7.12	0.43	1.18	0.18

Table B13 Effects of input frequency on product selectivities under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5kV; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Frequency (Hz)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
290	62.43	61.38	6.07	16.68	3.98
300	68.22	59.92	6.02	18.12	4.43
350	62.01	57.86	6.20	15.81	3.95
400	69.11	56.53	6.17	18.00	4.86
500	83.29	57.71	6.89	19.11	5.72

TableB14 Effects of input frequency on product molar ratios under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5kV; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Frequency (Hz)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
290	1.83	37.04	13.47	2.75
300	2.07	41.14	13.67	3.01
350	1.91	35.74	14.01	2.55
400	2.18	40.00	13.71	2.92
500	2.53	42.39	15.29	2.77

Table B15 Effects of input frequency on power consumptions and coke formation under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5kV; and electrode gap distance, 6 mm (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Input Frequency (Hz)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
290	2.16	1.47
300	1.98	1.22
350	2.01	1.40
400	2.19	1.36
500	3.06	1.60

Table B16 Effects of electrode gap distance on reactant conversions and product yields under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5 kV; and input frequency, 300 Hz (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Electrode Gap Distance (mm)	Reactant conversion (%)					Product yield (%)		
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	C_2	CO
4	15.71	18.27	21.57	0.46	20.73	49.75	11.66	32.08
6	22.28	31.22	39.42	-2.81	34.61	63.39	21.75	53.99
7	28.11	39.36	48.32	-1.72	42.93	70.96	24.47	69.49
8	27.67	39.70	49.98	-1.16	43.29	69.83	25.54	67.67

Table B17 Effects of electrode gap distance on concentrations of outlet gas, (c) generated current under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5 kV; and input frequency, 300 Hz (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Electrode Gap Distance (mm)	Concentration of outlet gas (mol%)									
	CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
4	38.46	2.78	2.62	13.85	25.70	17.09	6.09	0.37	0.73	0.09
6	35.41	2.34	2.03	14.17	21.10	19.63	9.50	0.48	1.44	0.18
7	32.37	2.04	1.70	14.26	18.51	21.85	12.08	0.60	1.53	0.18
8	33.23	2.07	1.69	14.06	18.83	21.58	11.84	0.61	1.62	0.20

Table B18 Effects of electrode gap distance on product selectivities under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5 kV; and input frequency, 300 Hz (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Electrode Gap Distance (mm)	Product selectivity (%)				
	H_2	CO	C_2H_2	C_2H_4	C_4H_{10}
4	89.56	57.27	7.05	13.77	3.31
6	68.22	59.92	6.02	18.12	4.43
7	61.28	60.92	6.07	15.38	3.67
8	59.51	58.24	6.00	15.98	3.90

TableB19 Effects of electrode gap distance on product molar ratios under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5 kV; and input frequency, 300 Hz (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Electrode Gap Distance (mm)	Molar ratio			
	H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
4	2.81	45.61	23.34	1.95
6	2.07	41.14	13.67	3.01
7	1.81	36.29	14.32	2.53
8	1.82	35.35	13.28	2.66

Table B20 Effects of electrode gap distance on power consumptions and coke formation under studied conditions: steam content, 10 mol%; HCs/O_2 feed molar ratio, 2/1; total feed flow rate, 100 cm^3/min; input voltage, 14.5 kV; and input frequency, 300 Hz (E_c: power per reactant molecule converted; E_{H2}: power per H_2 molecule produced).

Electrode Gap Distance (mm)	Power consumption ($\times 10^{18}$ Ws/molecule)	
	per reactant converted	per H_2 produced
4	3.36	1.69
6	1.98	1.22
7	2.04	1.43
8	2.00	1.45

Appendix C Experimental data

Table C1 Effect of stage number of plasma reactors on reactant conversions and product yields for the combined steam reforming and partial oxidation of natural gas at a constant feed flow rate of 100 cm^3/min (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Residence time (s)	Number of stage	Reactant conversion (%)					Product yield (%)		
		CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	C_2	CO
1.37	1	22.28	31.22	39.42	-2.81	34.62	63.38	21.75	53.99
2.74	2	37.55	38.76	55.26	-5.45	26.12	106.57	30.99	106.71
4.11	3	39.58	45.60	68.95	7.78	36.79	120.75	41.35	134.84
5.48	4	52.22	52.94	76.10	4.70	43.30	121.51	43.37	158.39

Table C2 Effect of stage number of plasma reactor on concentrations of outlet gas for the combined steam reforming and partial oxidation of natural gas at a constant feed flow rate of 100 cm^3/min (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Residence time (s)	Number of stage	Concentration of outlet gas (mol%)								
		H_2	CO	CH_4	CO_2	C_2H_2	C_2H_4	C_2H_6	C_3H_8	C_4H_{10}
1.37	1	19.63	9.49	35.41	14.16	0.477	1.437	2.343	2.030	0.176
2.74	2	35.28	19.84	27.54	12.21	1.057	1.825	1.943	1.366	0.179
4.11	3	39.74	24.51	28.17	11.83	1.570	2.189	1.822	1.039	0.262
5.48	4	41.62	29.65	21.69	10.83	1.939	2.122	1.529	0.746	0.203

Table C3 Effect of stage number of plasma reactors on product selectivities for the combined steam reforming and partial oxidation of natural gas at a constant feed flow rate of 100 cm^3/min (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Residence time (s)	Number of stage	Product selectivity (%)				
		H_2	C_2H_2	C_2H_4	CO	C_4H_{10}
1.37	1	68.216	6.020	18.122	59.915	4.434
2.74	2	81.002	9.009	15.565	84.618	3.061
4.11	3	78.345	10.665	14.875	83.285	3.554
5.48	4	67.038	11.135	12.191	85.175	2.332

Table C4 Effect of stage number of plasma reactors on product molar ratio for the combined steam reforming and partial oxidation of natural gas at a constant feed flow rate of 100 cm^3/min and (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Residence time (s)	Number of stage	Molar ratio			
		H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
1.37	1	2.067	41.136	13.666	3.010
2.74	2	1.778	33.401	19.334	1.728
4.11	3	1.621	25.323	18.156	1.395
5.48	4	1.404	21.473	19.614	1.095

Table C5 Effect of stage number of plasma reactor on power consumptions and coke formation for the combined steam reforming and partial oxidation of natural gas at a constant feed flow rate of 100 cm^3/min and (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Residence time (s)	Number of stage	Power consumption ($\times 10^{-17}$ Ws/molecule)	
		per reactant converted	per H_2 produced
1.37	1	19.784	12.244
2.74	2	18.735	10.007
4.11	3	3.485	2.043
5.48	4	8.106	5.520

Table C6 Effect of stage number of plasma reactors on reactant conversions and product yields for the combined steam reforming and partial oxidation of natural gas at constant residence time of 4.11 s (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Feed flow rate (cm^3/min)	Number of stage	Reactant conversion (%)					Product yield (%)		
		CH_4	C_2H_6	C_3H_8	CO_2	O_2	H_2	C_2	CO
33.3	1	35.10	40.52	56.50	-1.58	35.96	118.70	34.40	122.56
66.6	2	39.82	45.17	68.31	6.11	30.83	124.36	43.95	139.49
100.0	3	39.58	45.60	68.95	7.78	36.79	120.76	41.35	134.84
133.3	4	39.29	47.35	70.49	-2.04	45.02	119.35	46.48	121.46

Table C7 Effect of stage number of plasma reactor on concentrations of outlet gas for the combined steam reforming and partial oxidation of natural gas at constant residence time of 4.11 s (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Feed flow rate (cm^3/min)	Number of stage	Concentration of outlet gas (mol%)								
		H_2	CO	CH_4	CO_2	C_2H_2	C_2H_4	C_2H_6	C_3H_8	C_4H_{10}
33.3	1	38.07	21.99	28.99	11.92	1.491	1.594	1.929	1.359	0.169
66.6	2	39.57	24.52	27.07	11.63	1.800	2.062	1.761	0.998	0.236
100.0	3	39.75	24.51	28.17	11.83	1.570	2.189	1.822	1.039	0.262
133.3	4	38.80	22.26	28.52	12.53	1.899	2.362	1.784	0.979	0.276

Table C8 Effect of stage number of plasma reactors on product selectivities for the combined steam reforming and partial oxidation of natural gas at constant residence time of 4.11 s (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Feed flow rate (cm^3/min)	Number of stage	Product selectivity (%)				
		H_2	C_2H_2	C_2H_4	CO	C_4H_{10}
33.3	1	89.839	12.735	13.615	93.88	2.885
66.6	2	81.124	12.851	14.718	87.50	3.368
100.0	3	78.345	10.665	14.875	83.28	3.554
133.3	4	75.956	13.358	16.613	78.31	3.882

Table C9 Effect of stage number of plasma reactors on product molar ratio for the combined steam reforming and partial oxidation of natural gas at constant residence time of 4.11 s (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Feed flow rate (cm^3/min)	Number of stage	Molar ratio			
		H_2/CO	H_2/C_2H_2	H_2/C_2H_4	C_2H_4/C_2H_2
33.3	1	1.731	25.523	23.874	1.069
66.6	2	1.614	21.976	19.189	1.145
100.0	3	1.621	25.323	18.156	1.395
133.3	4	1.743	20.433	16.429	1.244

Table C10 Effect of stage number of plasma reactor on power consumptions and coke formation for the combined steam reforming and partial oxidation of natural gas at constant residence time of 4.11 s (steam content, 10 mol%; HCs-to-O_2 feed molar ratio, 2/1 (Oxygen content of 33.33 mol%); input voltage, 14.5 kV; input frequency, 300 Hz; and electrode gap distance, 6 mm).

Feed flow rate (cm^3/min)	Number of stage	Power consumption ($\times 10^{-17}$ Ws/molecule)	
		per reactant converted	per H_2 produced
33.3	1	52.483	25.483
66.6	2	14.881	8.375
100.0	3	3.485	2.043
133.3	4	8.960	5.115

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1. Pommai, K.; Jindanin, A.; Sekiguchi, H.; Chavadej, S. Synthesis Gas production from CO_2-Containing Natural Gas by Combined Steam Reforming and Partial Oxidation in an AC Gliding Arc Discharge. Plasma Chemistry and Plasma Processing. (accepted)

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1. Pommai, K.; Sreethawong, T.; and Chavadej, S. (2009) Steam Reforming of CO_2-Containing Natural Gas Using an AC Gliding Arc Discharge System. Paper presented at The 19th International Symposium on Plasma Chemistry, July 26–31, Bochum, Germany.
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