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APPENDICES

Appendix A Experimental Data of Gas Calibration of GC-8A

Condition :Detector Current 140 mA

Temperature	°C
Column	25
Detector	120
TCD-T	120
Pressure	**kPa**
Carrier Pressure (Primary)	600
Carrier Pressure (1)	50
TCD-Ref	10

Column	Model
Alltech	CTR I

1. Methane

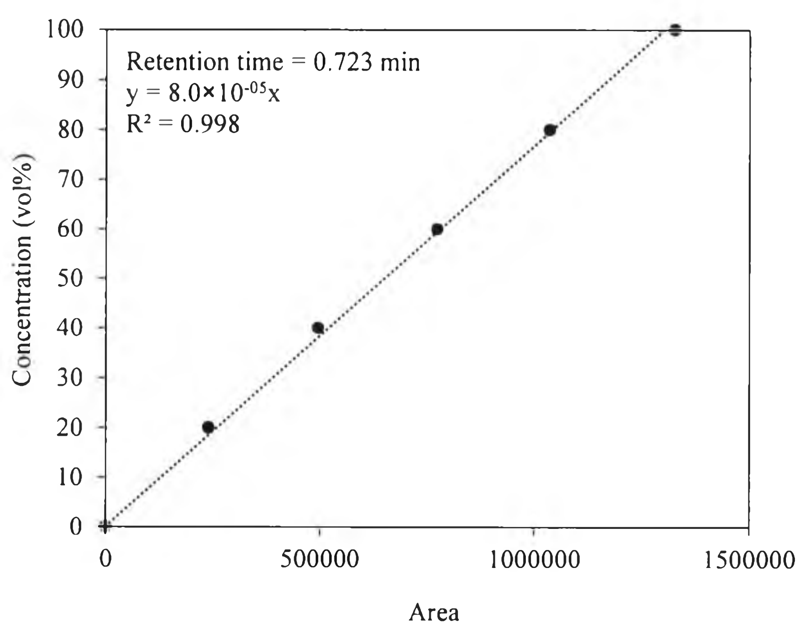

Figure A1 Relationship between area and concentration of methane.

2. Carbon Dioxide

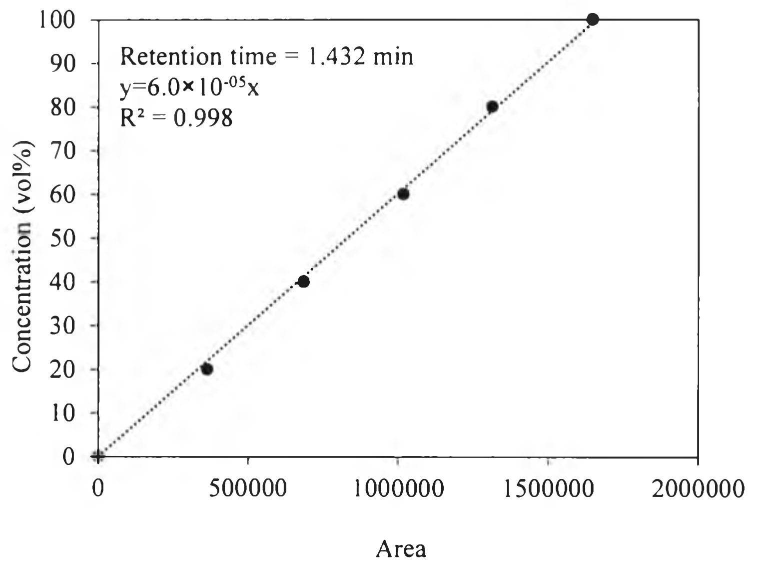

Figure A2 Relationship between area and concentration of carbon dioxide.

3. Hydrogen

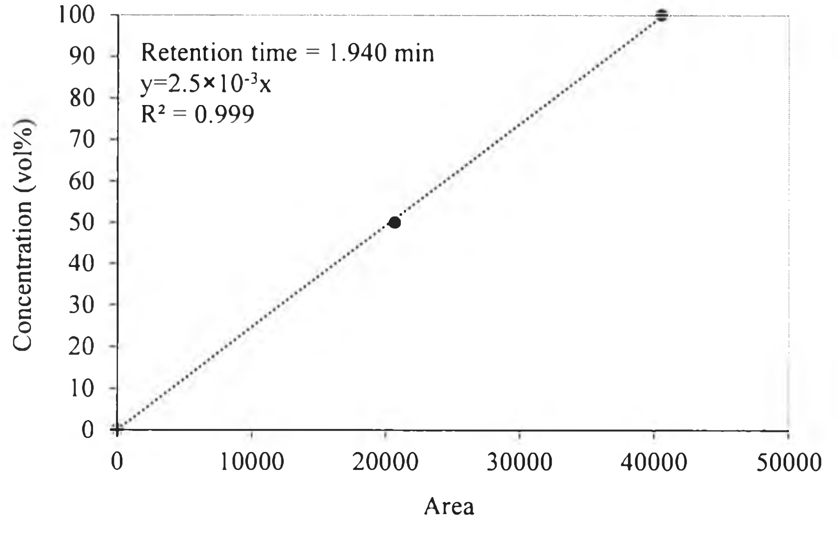

Figure A3 Relationship between area and concentration of hydrogen.

4. Carbon monoxide

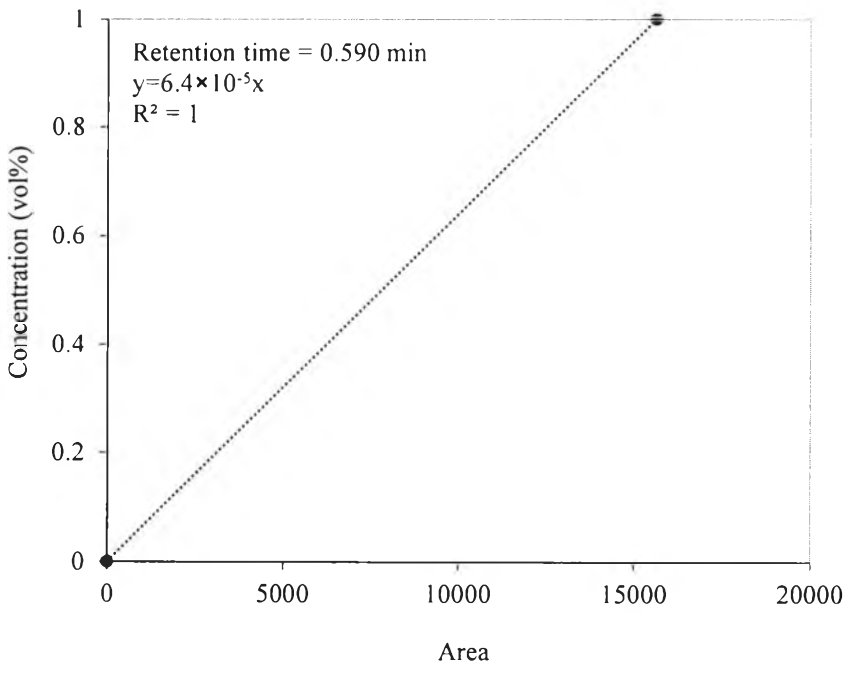

Figure A4 Relationship between area and concentration of carbon monoxide.

Appendix B Calibration of Brooks 5850E Mass Flow Controllers

1. Methane

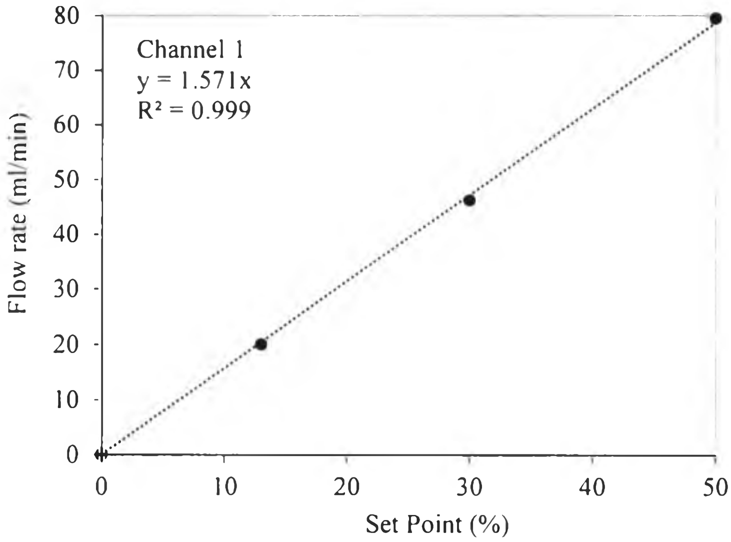

Figure B1 Relationship between SP and flow rate of methane.

2. Hydrogen

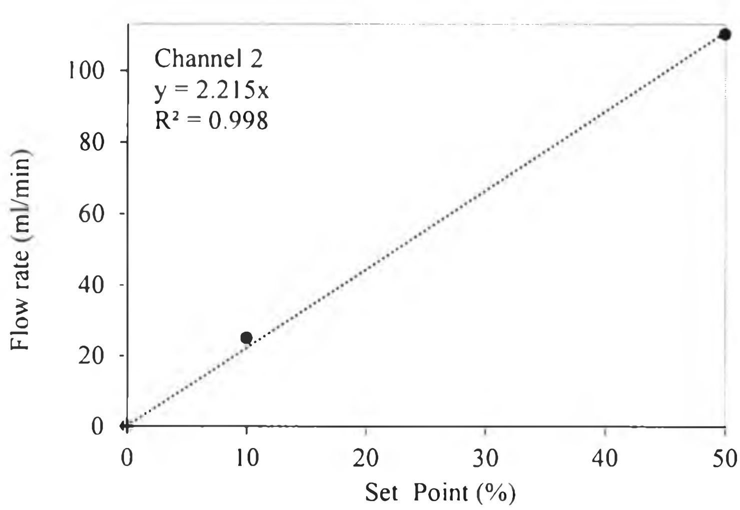

Figure B2 Relationship between SP and flow rate of hydrogen.

3. Carbon Dioxide

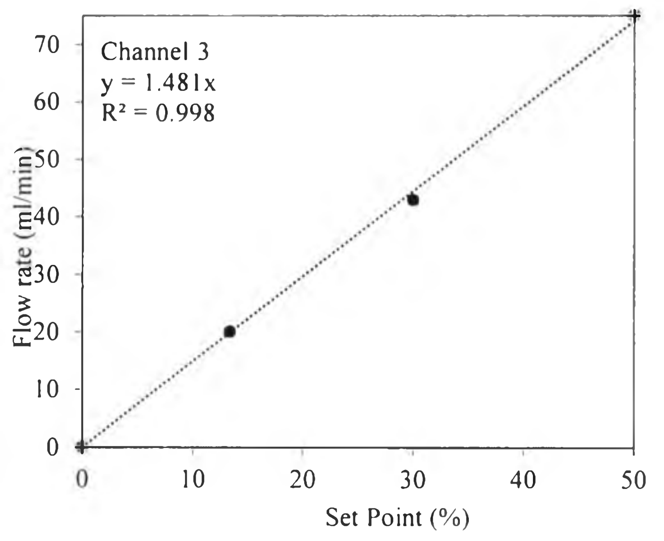

Figure B3 Relationship between SP and flow rate of carbon dioxide.

4. Helium

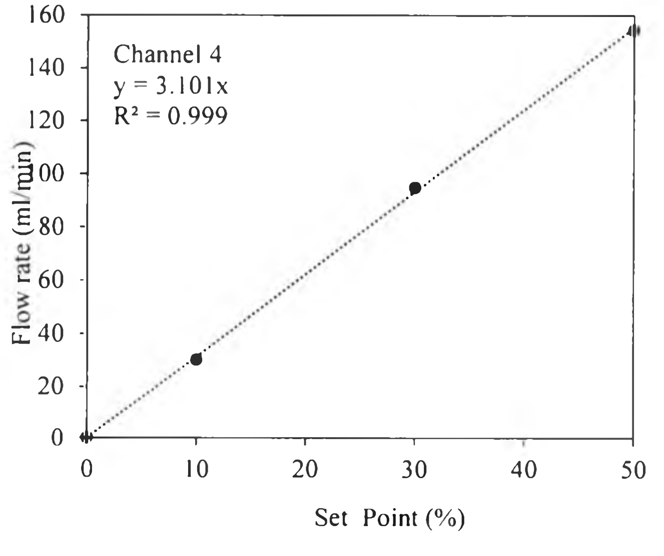

Figure B4 Relationship between SP and flow rate of helium.

Appendix C Experimental Data of Catalytic Activity Tests for Methane Dry Reforming

Table C1 Catalytic activity test of Ni/CZO-S catalyst at various temperature, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Temperature (°C)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
500	10.9	18.2	19.3	16.4	0.85
550	24.2	31.0	26.9	25.2	0.93
600	37.3	44.5	37.5	35.5	0.94
650	48.7	59.4	52.8	46.0	0.87
700	61.4	69.4	61.5	55.4	0.90
750	74.1	79.6	69.1	64.0	0.93
800	84.1	87.3	75.8	70.3	0.93
850	90.1	92.6	78.7	75.5	0.96
900	91.9	95.5	79.6	78.2	0.98

Table C2 Catalytic activity test of Ni/CZN-1 catalyst at various temperature, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Temperature (°C)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
500	12.6	22.9	25.6	19.1	0.75
550	28.2	35.8	35.1	28.7	0.82
600	46.3	51.3	52.3	40.0	0.76
650	62.5	66.8	66.6	51.7	0.78
700	73.8	76.6	74.3	61.6	0.83
750	82.4	84.2	77.5	69.2	0.89
800	88.0	89.3	80.5	74.0	0.92
850	91.7	94.4	82.6	78.1	0.94
900	92.3	95.0	83.6	79.5	0.95

Table C3 Catalytic activity test of Ni/CZN-2 catalyst at various temperature, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Temperature (°C)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
500	15.2	22.7	15.5	17.8	1.15
550	29.4	34.9	25.8	27.0	1.04
600	45.3	49.9	39.7	38.3	0.96
650	59.6	64.6	56.5	50.4	0.89
700	72.1	76.1	66.0	59.7	0.90
750	81.3	83.7	73.9	66.2	0.89
800	87.8	89.3	80.0	71.1	0.89
850	90.3	94.4	83.8	76.0	0.91
900	91.1	96.5	84.6	77.8	0.92

Table C4 Catalytic activity test of Ni/CZO-C catalyst at various temperature, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Temperature (°C)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
500	12.7	15.8	22.3	17.7	0.79
550	26.9	29.7	35.7	28.7	0.80
600	45.9	47.8	47.4	41.3	0.87
650	57.6	62.1	59.2	53.4	0.90
700	70.3	74.2	68.6	63.8	0.93
750	81.0	83.4	75.2	71.2	0.94
800	91.2	90.5	82.3	75.8	0.92
850	94.1	95.1	84.7	78.8	0.93
900	94.8	97.4	86.6	79.9	0.93

Table C5 Catalytic activity test of Ni/CZM-1 catalyst at various temperature, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Temperature (°C)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
500	18.7	24.0	27.5	23.9	0.87
550	40.4	41.6	37.0	36.2	0.98
600	65.4	61.4	59.8	52.6	0.88
650	79.8	79.0	76.7	67.8	0.88
700	89.2	87.9	82.7	74.7	0.90
750	93.9	92.4	86.7	78.4	0.90
800	94.8	95.1	87.5	81.3	0.93
850	95.3	97.5	89.9	84.0	0.93
900	95.7	98.2	89.4	84.4	0.94

Table C6 Catalytic activity test of Ni/CZM-2 catalyst at various temperature, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Temperature (°C)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
500	16.2	25.5	19.3	20.6	1.06
550	42.9	48.3	36.0	38.9	1.09
600	54.4	58.7	60.7	48.6	0.80
650	73.6	76.3	75.6	64.3	0.85
700	84.3	85.1	79.7	71.5	0.89
750	90.3	89.6	82.6	75.4	0.91
800	94.1	93.5	84.0	77.7	0.93
850	95.1	96.5	87.0	80.4	0.93
900	95.7	95.4	87.1	81.5	0.93

Appendix D Experimental Data of Stability Tests for Methane Dry Reforming

Table D1 Stability test of Ni/CZO-S catalyst at 750 °C, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Time (hr)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
1	70.3	69.3	72.5	66.8	0.93
2	65.5	67.0	67.9	64.5	0.95
3	62.8	65.6	66.4	63.9	0.96
4	61.3	64.9	66.0	62.6	0.95
5	59.9	64.2	61.4	61.5	1.00
6	59.2	63.7	61.4	60.7	0.99
7	59.7	64.0	61.4	60.8	0.99
8	58.9	63.3	61.4	59.7	0.97
9	58.7	63.2	59.8	59.0	0.99
10	57.2	61.9	56.0	61.9	0.93

Table D2 Stability test of Ni/CZN-1 catalyst at 750 °C, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Time (hr)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
1	75.2	75.5	74.0	62.7	0.85
2	74.6	76.0	68.4	63.4	0.93
3	73.1	75.5	67.2	63.5	0.95
4	73.8	76.6	70.0	64.2	0.93
5	73.6	76.6	67.7	62.7	0.93
6	73.1	75.5	67.2	63.5	0.95
7	72.3	75.6	67.7	63.4	0.94
8	73.8	76.6	70.0	64.2	0.93
9	72.3	75.6	67.7	63.4	0.94
10	72.3	75.6	67.7	63.4	0.85

Table D3 Stability test of Ni/CZN-2 catalyst at 750 °C, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Time (hr)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
1	73.4	75.5	73.4	66.1	0.90
2	72.9	75.4	72.8	66.1	0.91
3	67.0	69.7	67.5	61.2	0.91
4	66.2	69.8	68.8	60.8	0.88
5	66.5	70.7	68.1	61.2	0.90
6	-	-	-	-	-
7	-	-	-	-	-
8	-	-	-	-	-
9	-	-	-	-	-
10	-	-	-	-	-

Table D4 Stability test of Ni/CZO-C catalyst at 750 °C molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Time (hr)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
1	51.8	62.4	51.4	51.8	1.01
2	50.4	60.3	51.0	51.0	1.00
3	49.6	59.6	52.4	50.3	0.96
4	49.5	59.6	49.7	49.6	1.00
5	48.9	59.3	49.4	49.3	1.00
6	48.8	59.1	49.2	49.1	1.00
7	48.2	58.8	48.5	49.0	1.01
8	47.8	58.5	50.4	49.1	0.97
9	47.5	58.3	48.2	49.1	1.02
10	47.1	58.3	49.2	48.8	1.01

Table D5 Stability test of Ni/CZM-1 catalyst at 750 °C, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Time (hr)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
1	83.4	82.8	83.2	82.6	0.99
2	82.0	81.9	84.7	85.2	1.01
3	81.9	82.3	83.8	84.9	1.02
4	82.6	83.0	89.2	83.2	0.93
5	82.8	82.9	86.5	82.8	0.95
6	82.4	83.0	86.2	82.0	0.94
7	81.8	82.4	86.6	82.4	0.94
8	81.7	82.3	84.7	81.8	0.96
9	81.5	82.1	84.6	81.5	0.96
10	81.1	81.8	85.0	81.1	0.99

Table D6 Stability test of Ni/CZM-2 catalyst at 750 °C, molar ratio of $CH_4/CO_2/He$ = 1:1:8 with GHSV of 10,600 h^{-1}

Time (hr)	X_{CH_4}(%)	X_{CO_2}(%)	Y_{CO} (%)	Y_{H_2} (%)	H_2/CO
1	74.9	77.8	72.9	65.7	0.90
2	74.1	77.3	71.6	65.3	0.91
3	74.2	77.7	71.2	65.7	0.93
4	72.8	76.7	70.6	64.4	0.91
5	72.4	76.3	70.3	64.2	0.92
6	72.1	76.2	70.2	63.6	0.91
7	71.4	75.6	68.1	63.0	0.93
8	72.1	75.9	69.3	62.7	0.91
9	71.9	75.9	71.5	62.2	0.87
10	71.8	75.6	69.6	62.5	0.90

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Proceedings:

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