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APPENDICES

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

Condition: Detector Current 80 mA

Temperature	**°C**
Column	50
Detector	100
TCD-T	100
Pressure	**kPa**
Carrier Pressure (Primary)	600
Carrier Pressure (1)	550
TCD-Ref	10

Column	Model
P/W HAYESEP DB	HP model 5890 SERIES 2

1. Methane

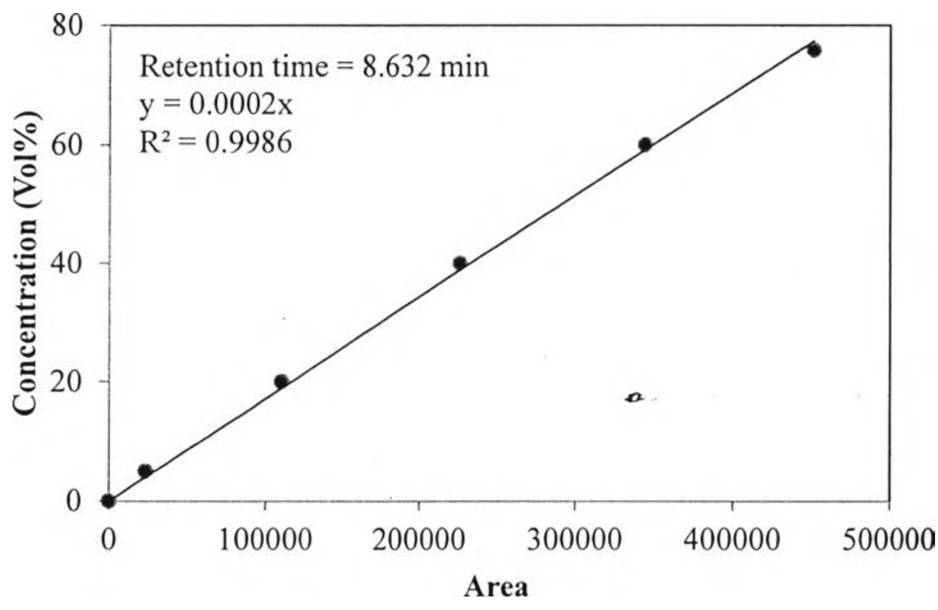

Figure A1 Relationship between area and concentration of methane.

2. **Carbon dioxide**

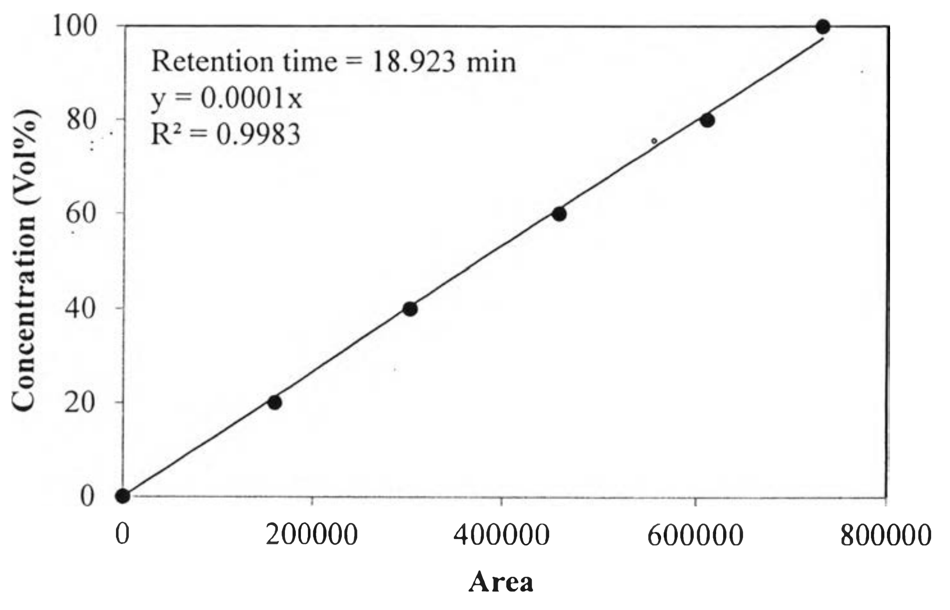

Figure A2 Relationship between area and concentration of carbon dioxide.

3. **Hydrogen**

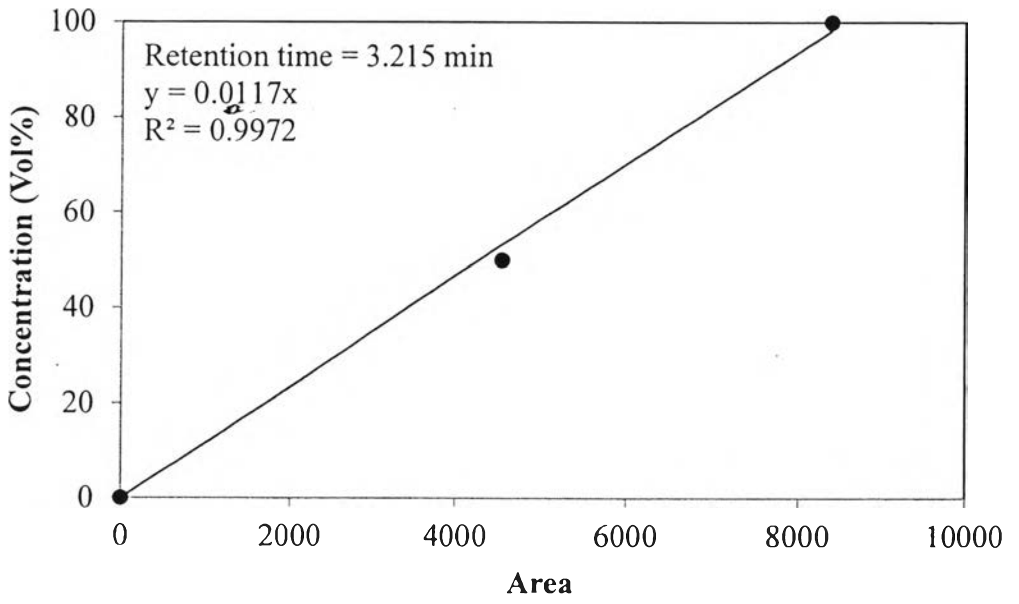

Figure A3 Relationship between area and concentration of hydrogen.

4. Carbon monoxide

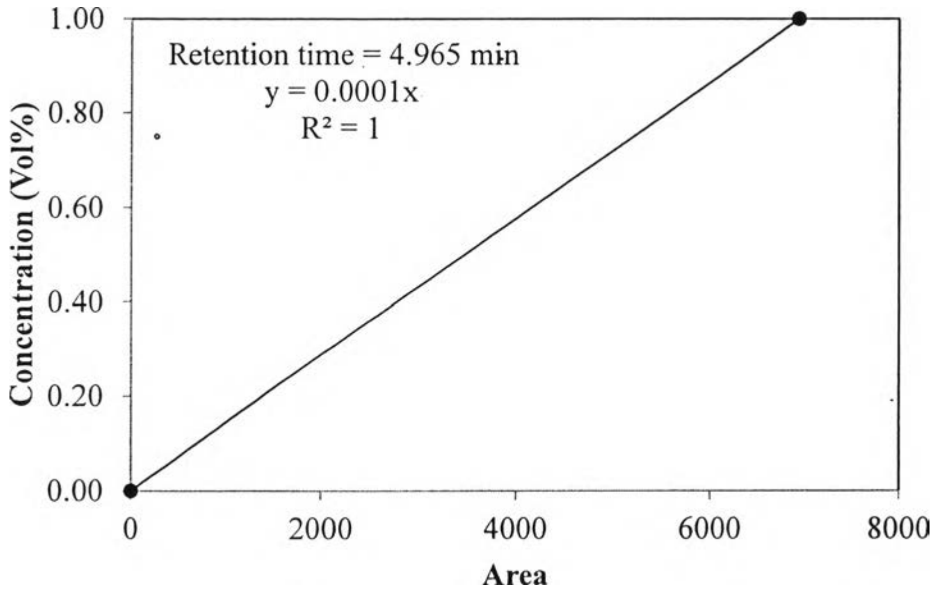

Figure A4 Relationship between area and concentration of carbon monoxide.

5. Oxygen

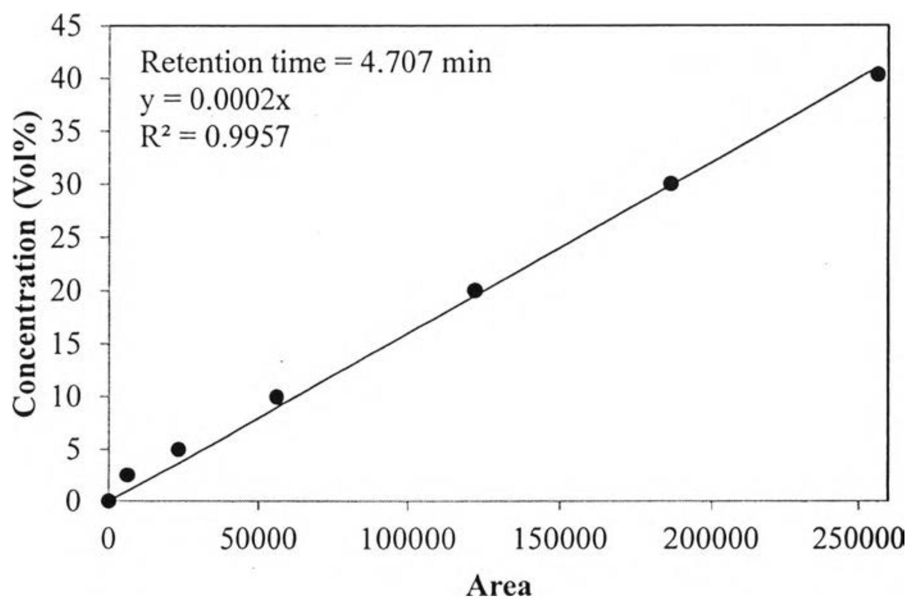

Figure A5 Relationship between area and concentration of oxygen.

6. **Nitrogen**

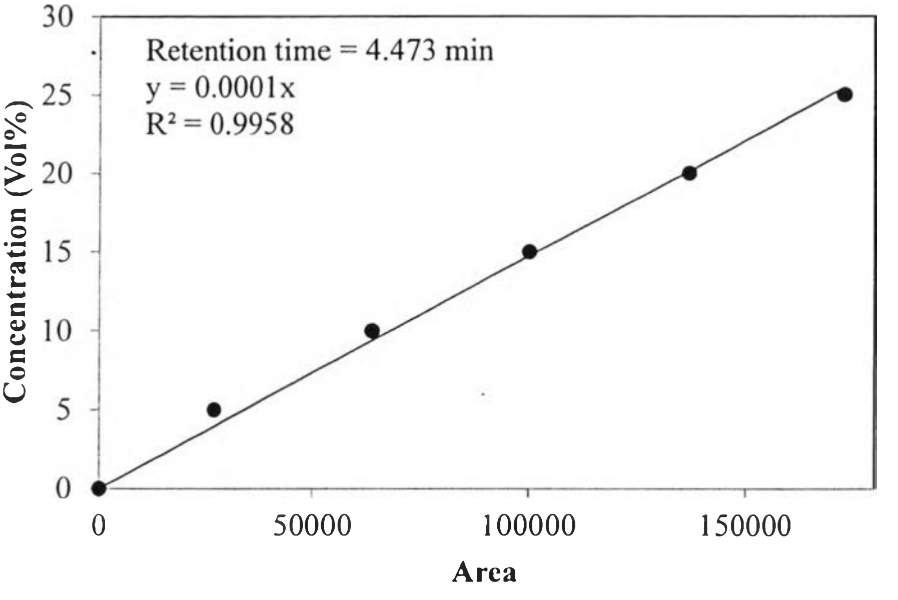

Figure A6 Relationship between area and concentration of nitrogen.

Appendix B Calibration of Brooks 5850E Mass Flow Controllers

1. Methane

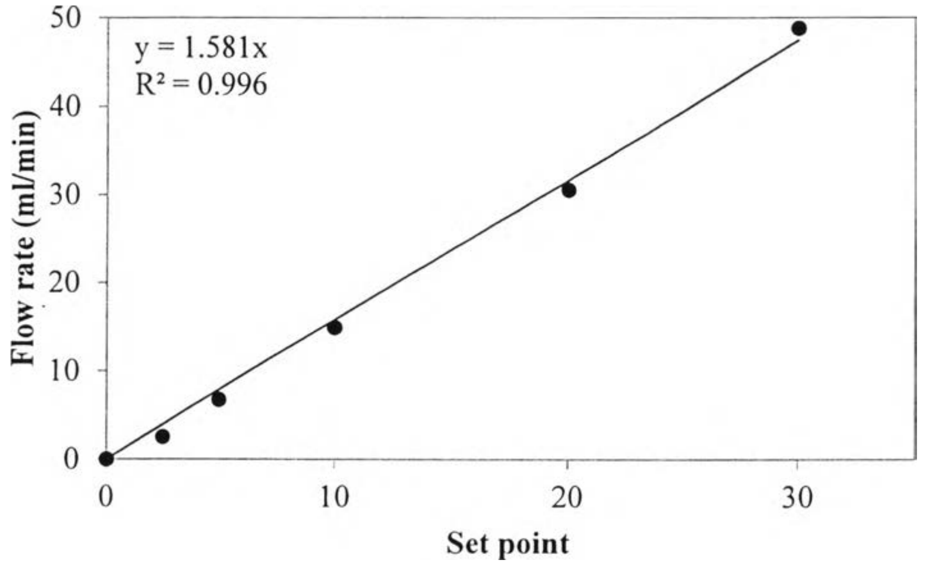

Figure B1 Relationship between SP and flow rate of methane.

2. Air

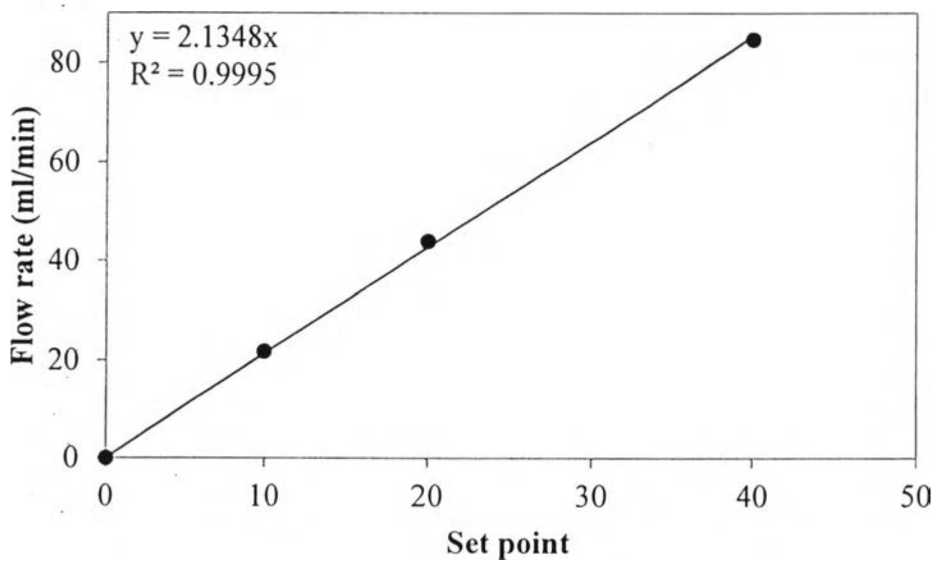

Figure B2 Relationship between SP and flow rate of air.

3. Helium

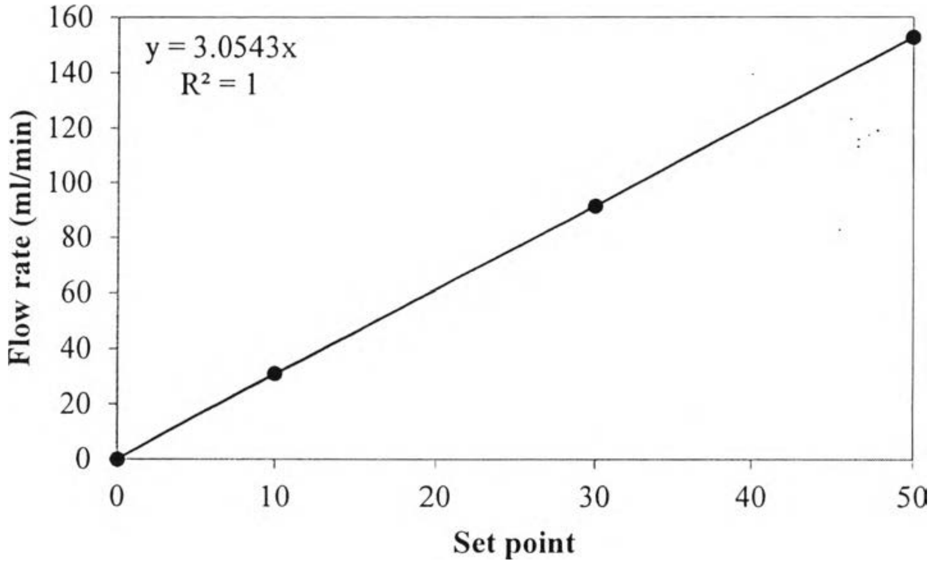

Figure B3 Relationship between SP and flow rate of helium.

Appendix C Experimental Data of Catalytic Activity Tests for MPO

Table C1 Catalytic activity test of 5Ni/CZOi catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
401	0.15	1.64	0.00	0.00	0.00	0.00
452	1.21	9.05	0.00	0.00	0.00	0.00
503	6.01	37.26	0.00	0.00	0.00	0.00
559	9.32	52.41	0.00	0.00	0.00	0.00
602	63.77	100.00	87.24	77.67	27.54	35.02
658	64.36	100.00	88.10	82.17	29.05	38.25
705	65.74	100.00	89.50	85.03	31.97	41.95
753	66.79	100.00	90.36	88.48	34.08	43.03
809	67.75	100.00	91.59	90.43	37.10	45.79

Table C2 Catalytic activity test of 5Ni/CZOp catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
400	2.77	2.42	0.00	0.00	0.00	0.00
450	3.99	10.62	0.00	0.00	0.00	0.00
501	10.72	40.40	0.00	0.00	0.00	0.00
553	17.18	53.19	0.00	0.00	0.00	0.00
603	67.02	100.00	89.94	83.43	33.40	46.01
653	68.55	100.00	89.78	86.09	33.85	46.58
705	69.40	100.00	90.81	88.22	36.32	46.95
753	70.46	100.00	91.29	90.79	37.90	47.02
808	71.41	100.00	91.57	91.33	39.06	47.45

Table C3 Catalytic activity test of 10Ni/CZOi catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
402	0.31	2.66	0.00	0.00	0.00	0.00
453	2.26	9.91	0.00	0.00	0.00	0.00
504	8.10	38.04	0.00	0.00	0.00	0.00
557	11.00	52.95	0.00	0.00	0.00	0.00
603	65.24	100.00	87.03	76.29	27.87	39.73
657	66.49	100.00	88.64	79.03	30.88	41.18
708	67.83	100.00	90.04	83.69	33.99	43.27
757	68.45	100.00	91.37	85.14	36.99	45.02
811	68.78	100.00	92.76	88.04	40.39	46.79

Table C4 Catalytic activity test of 10Ni/CZOp catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	**X_{CH4} (%)**	**X_{O2} (%)**	**S_{H2} (%)**	**S_{CO} (%)**	**Y_{H2} (%)**	**Y_{CO} (%)**
400	5.39	3.21	0.00	0.00	0.00	0.00
452	6.24	10.23	0.00	0.00	0.00	0.00
503	12.60	41.97	0.00	0.00	0.00	0.00
554	18.65	53.98	0.00	0.00	0.00	0.00
604	68.33	100.00	89.59	82.66	33.40	46.01
654	69.07	100.00	89.97	86.31	34.48	48.24
706	70.45	100.00	91.16	89.30	37.62	48.94
756	72.55	100.00	91.48	91.28	39.48	50.09
809	72.83	100.00	92.03	91.60	40.94	50.45

Table C5 Catalytic activity test of 15Ni/CZOi catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
402	.6600	5.63	0.00	0.00	0.00	0.00
455	4.64	18.05	0.00	0.00	0.00	0.00
507	12.51	46.96	0.00	0.00	0.00	0.00
560	18.91	76.17	0.00	0.00	0.00	0.00
608	77.58	100.00	90.34	72.76	39.54	47.93
659	80.75	100.00	91.25	77.32	43.34	53.12
709	84.72	100.00	90.94	78.95	44.67	55.47
760	85.77	100.00	91.64	81.99	47.10	59.17
812	85.83	100.00	90.77	83.60	44.82	57.29

Table C6 Catalytic activity test of 15Ni/CZOp catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
401	7.53	14.64	0.00	0.00	0.00	0.00
453	8.90	23.20	0.00	0.00	0.00	0.00
504	16.39	48.79	0.00	0.00	0.00	0.00
555	23.13	82.41	0.00	0.00	0.00	0.00
604	80.40	100.00	90.37	75.60	41.05	53.33
655	83.20	100.00	91.41	79.27	45.07	57.62
705	87.03	100.00	92.15	82.16	49.27	57.95
757	87.88	100.00	92.05	85.80	49.44	62.41
809	89.16	100.00	92.00	86.18	50.01	63.22

Table C7 Catalytic activity test of 25Ni/CZOi catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
405	7.53	4.86	0.00	0.00	0.00	0.00
457	8.90	14.14	0.00	0.00	0.00	0.00
509	16.39	43.29	0.00	0.00	0.00	0.00
562	23.13	64.62	0.00	0.00	0.00	0.00
609	80.40	100.00	87.99	70.83	33.35	41.54
660	83.20	100.00	88.88	74.46	34.99	44.77
710	87.03	100.00	88.29	78.56	36.20	45.47
763	87.88	100.00	88.84	79.73	37.77	46.54
814	89.16	100.00	89.61	82.95	39.59	48.96

Table C8 Catalytic activity test of 25Ni/CZOp catalyst (CH_4/O_2 ratio = 2:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
402	7.53	4.55	0.00	0.00	0.00	0.00
454	8.90	15.66	0.00	0.00	0.00	0.00
505	16.39	36.12	0.00	0.00	0.00	0.00
556	23.13	67.66	0.00	0.00	0.00	0.00
605	80.40	100.00	89.47	77.81	38.34	50.33
656	83.20	100.00	89.21	79.30	38.86	51.06
705	87.03	100.00	89.56	81.16	41.31	54.11
758	87.88	100.00	90.71	85.00	44.68	57.57
808	89.16	100.00	90.66	87.40	45.43	58.36

Table C9 Catalytic activity test of 15Ni/CZOi catalyst (CH_4/O_2 ratio = 4:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
405	0.32	5.11	0.00	0.00	0.00	0.00
455	2.14	12.50	0.00	0.00	0.00	0.00
507	6.15	35.36	0.00	0.00	0.00	0.00
556	10.63	63.02	0.00	0.00	0.00	0.00
606	53.37	100.00	83.57	83.57	19.27	25.61
655	57.22	100.00	88.02	88.02	25.72	30.45
707	61.47	100.00	89.07	89.07	29.20	34.44
757	66.17	100.00	88.68	88.68	30.79	37.01
808	67.49	100.00	87.28	87.28	29.20	36.41

Table C10 Catalytic activity test of 15Ni/CZOp catalyst (CH_4/O_2 ratio = 4:1)

Temperature (°C)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)	Y_{H2} (%)	Y_{CO} (%)
401	2.48	12.44	0.00	0.00	0.00	0.00
453	6.63	21.19	0.00	0.00	0.00	0.00
504	13.57	44.70	0.00	0.00	0.00	0.00
555	19.57	62.44	0.00	0.00	0.00	0.00
604	69.01	100.00	86.35	90.61	28.49	33.05
655	70.99	100.00	89.23	94.82	34.04	37.95
705	73.24	100.00	89.27	94.23	35.18.	39.06
757	75.12	100.00	88.67	93.81	34.93	39.80
809	75.87	100.00	88.21	93.45	34.44	40.41

Appendix D Experimental Data of Stability Tests for MPO

Table D1 Stability test of 15Ni/CZOi catalyst (CH_4/O_2 ratio = 2:1)

Time (hr)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)
1	85.84	100.00	92.05	81.16
2	85.60	100.00	92.14	81.24
3	85.30	100.00	91.89	81.10
4	85.84	100.00	91.86	81.31
5	85.86	100.00	92.08	80.93
6	85.58	100.00	91.58	80.73

Table D2 Stability test of 15Ni/CZOp catalyst (CH_4/O_2 ratio = 2:1)

Time (hr)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)
1	87.67	100.00	92.16	85.81
2	87.52	100.00	92.18	86.72
3	87.80	100.00	92.22	86.07
4	87.81	100.00	92.16	85.98
5	87.76	100.00	92.07	85.49
6	87.68	100.00	92.18	84.48

Table D3 Stability test of 15Ni/CZOi catalyst (CH_4/O_2 ratio = 4:1)

Time (hr)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)
1	64.96	100.00	89.67	89.02
2	64.94	100.00	89.43	88.42
3	64.35	100.00	89.36	87.56
4	64.10	100.00	88.63	86.85
5	64.32	100.00	89.67	85.03
6	62.77	100.00	89.43	84.17

Table D4 Stability test of 15Ni/CZOp catalyst (CH_4/O_2 ratio = 4:1)

Time (hr)	X_{CH4} (%)	X_{O2} (%)	S_{H2} (%)	S_{CO} (%)
1	75.12	100.00	89.63	93.81
2	75.12	100.00	89.58	93.78
3	75.12	100.00	89.49	93.62
4	74.87	100.00	89.51	91.46
5	74.83	100.00	89.31	89.80
6	74.78	100.00	89.30	88.97

Appendix E Calculation of Metal Surface Area

The calculation of the metal surface area is based on the following relation:

$$MSS = (Vm\ Na) / (Sf\ Sd)$$

MSS = metal surface area (m^2/g of sample)

Vm = gas adsorded at monolayer (moles/gram of sample)

Na = Avogadro number (molecule/mole of gas) = 6.02×10^{23} molecule/mole

Sf = stoichiometric factor of the reaction (number of molecule of adsorbate/surface metal atom) = 0.5

Sd = Metal surface density (number of metal atoms/m^2) = 0.154×10^{20} atoms/m^2

For example

Metal Surface Area of 5Ni/CZOi

$$MSS = [(3.63223 \times 10^{-5}) \times (6.02 \times 10^{23})] / [0.5 \times (0.154 \times 10^{20})]$$

$$= 2.84\ m^2/g$$

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