REFERENCES

Astarita, G. et.al. (1983) Gas Treating with Chemical Solvents. New York: John Wiley.

Bello, A. and Idem, R.O. (2005) Pathways for the formation of products of the oxidative degradation of CO_2-loaded concentrated aqueous monoethanolamine solutions during CO_2 absorption from flue gases. Industrial & Engineering Chemistry Research, 44(4), 945-969.

Blanc, C, Grall, M., and, Demarais, G. (1982) The part played by degradation products in the corrosion of gas sweetening plants using DEA and MDEA. Paper presented at The 32nd Annual Laurance Reid Gas conditioning Conference, Oklahoma University, Oklahoma, USA.

Chakma, A, Mehrotra, A.K., and Nielson, B. (1995) Comparison of chemical solvents for mitigating CO_2 emissions from fired power plants. Heat Recovery Systems & CHP, 15(2), 231-240.

Chi, S. and Rochelle, G. T. (2002) Oxidative degradation of monoethanolamine. Industrial & Engineering Chemistry Research, 41(17), 4178-4186.

Goff, G. S. and Rochelle, G.T. (2003) Oxidative degradation of Aqueous Monoethanolamine in CO_2 capture systems under absorber conditions. 6th International conference on Greenhouse gas control technologies, Kyoto, Japan, 2003: Gale J., Kaya Y., Eds.; Elsevier: Oxford, UK 2003, pages 115-120.

Goff, G. S. and Rochelle, G.T. (2004) Monoethanolamine degradation: O_2 mass transfer effects under CO_2 capture conditions. Industrial & Engineering Chemistry Research, 43(20), 6400-6408.

Herzog, H.; Drake, E.; Adams, E. CO_2 Capture, Reuse, and Storage Technologies for Mitigating Global Climate Change. Report No. DE-AF22-96PC01257 (A White Paper), 1997; 1-66.

Hofmeyer, B.G, Scholten, H.G., and Lloyd, W.G. (1965) Contamination and corrosion in monoethanolamine gas treating solutions. Internal Report No. 722, The Dow Chemical Company, Midland.

Howard, M and Sargent, A. (2001) Operating experiences at duke energy field services wilcox plant with oxygen contamination and amine degradation. Paper presented at The 51st Annual Laurance Reid Gas conditioning Conference, Oklahoma University, Oklahoma, USA.

Kohl, A. L. and Nielson, R. B.; Gas Purification; Gulf Publishing; Houston, Texas. 1997.

Lawal, A.O., Bello, A., and Idem, R.O. (2005) The role of methyl diethanolamine (MDEA) in preventing the oxidative degradation of CO_2-loaded and concentrated aqueous monoethanolamine (MEA)-MDEA blend during CO_2 absorption from flue gases. Industrial & Engineering Chemistry Research, 44(6), 1874-1896.

Lawal, A.O. and Idem, R.O. (2006) Kinetics of the oxidative degradation of CO_2 loaded and concentrated aqueous MEA-MDEA blends during CO_2 absorption from flue gas streams. Industrial & Engineering Chemistry Research, 45(8), 2601-2607.

Maddox, R. N.: "Gas Conditioning and Liquid sweetening" 2nd Edition Campbell Petroleum Series, Norman, Oklahoma, 1974.

McCullough, J. G. and Nielson, R. B.: "Contamination and Purification of alkaline gas treating solutions" Paper 396, 1996.

McKnight, J.E. (1988) Air exclusion key to gathering-system upkeep. Oil & Gas Journal, Feb, 41-42.

Polderman, L.D, Dillon, C.P and Steele, A.B. (1950) Why MEA solution breaks down in gas treating service. Oil & Gas Journal, 69-71.

Rochelle, G.T. et al. (2002). Research results for CO_2 capture from flue gas by aqueous absorption/stripping. Paper presented at The 52nd Annual Laurance Reid Gas Conditioning Conference, Oklahoma University, Oklahoma, USA.

Rooney, P. C., Bacon, T.R., and Dupart, M.S. (1996). Effect of heat stable salts on MDEA solution corrosivity. Hydrocarbon Processing (International Edition), 75(March), 95-6+.

Rooney, P. C., Dupart, M.S., and Bacon, T.R. (1997) Part 2: effect of heat stable salts on MDEA solution corrosivity. Hydrocarbon Processing (International Edition), 76(April), 65-8+.

Rooney, P.C., Dupart, M.S., and Bacon, T.R. (1998) Oxygen's role in alkanolamine degradation. Hydrocarbon Processing (International Edition), 77(7), 109-113.

Rooney, P.C. and Dupart, M.S. (2000) Corrosion in alkanolamine plants: causes and minimization. Paper presented at Corrosion 2000: NACE International Annual Conference and Exposition, Orlando, USA.

Shrikar, C., Guptha, A., Humek, B.: "Advanced technology for the capture of CO_2 from flue gases". first National Conference on Carbon sequestration. Washinton D.C. May 15-17, 2001, 1-11.

Strazisar, B. R., Anderson, R.R., and White, C.M. (2003) Degradation pathways for monoethanolamine in a CO2 capture facility. Energy & Fuels, 17(4), 1034-1039.

Straizisar, B. R., Anderson, R. R. and White, C. M.; Degradation of MEA used in CO_2 capture from flue gas of a coal-fired electric power generation station. U.S. Department of Energy, National Energy Laboratory, clean air technology division. Pittsburgh, PA 15236. 2003, 1-80.

Supap, T. et.al. (2001) Kinetics of the oxidative degradation of aqueous monoethanolamine in flue gases treating unit. Industrial & Engineering Chemistry Research, 40(16), 3445-3450.

Tontiwachwuthikul, P.: "Research and development activities on high efficiency separation process technologies for CO_2 removal from industrial sources at the University of Regina, Canada."

Veldman, R.R. (2000) Alkanolamine solution corrosion mechanisms and inhibition for heat stable salts and CO_2. Paper presented at Corrosion 2000: NACE International Annual Conference and Exposition, Orlando, USA.

APPENDICES

Appendix A Concentration-Degradation Rate Time Data of Oxidative Degradation Inhibitors for MEA Experiments

Table A1 Run number 1: 7 kmol/m^3 MEA, 100% O_2, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	6.97	6.55	0.014103
2	6.29	6.52	0.014042
24	6.04	6.22	0.013392
70.5	5.57	5.63	0.012116
94.5	5.33	5.34	0.011506
118.5	5.17	5.07	0.010926
142.5	4.8	4.82	0.010376
			Average = .012352

Table A2 Run number 2: 7 kmol/m^3 MEA, 100% O_2, 0.1 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	6.79	7.13	0.025547
2	7.05	7.08	0.025364
12	6.82	6.83	0.024471
24	6.77	6.54	0.023441
49	6.15	5.98	0.021432
72	5.74	5.51	0.019736
96	4.88	5.05	0.018110

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
120	4.56	4.64	0.016617
144	4.26	4.25	0.015248
			Average = 0.021107

Table A3 Run number 3: 5 kmol/m^3 MEA, 6% O_2, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.16	5.14	0.00045
20	5.13	5.13	0.0004493
44	5.1	5.12	0.0004483
68	5.09	5.11	0.0004474
117.5	5.1	5.08	0.0004454
			Average = 0.000448

Table A4 Run number 4: 5 kmol/m^3 MEA, 6% O_2, 0.3 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.3	5.18	0.001298
1	5.15	5.18	0.001298
2	5.14	5.18	0.001298
24	5.15	5.15	0.00129
48	5.07	5.12	0.001283
97	5.06	5.06	0.001267
144	5.02	5	0.001252
			Average = 0.001284

Table A5 Run number 5: 5 kmol/m^3 MEA, 6% O_2, 0.1 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.25	5.21	0.000656
2	5.22	5.21	0.000656
7	5.17	5.21	0.000656
18	5.2	5.20	0.000655
24	5.2	5.18	0.000654
48	5.17	5.15	0.000652
75	5.15	5.12	0.000650
96	5.17	5.21	0.000649
			Average = 0.000654

Table A6 Run number 6: 5 kmol/m^3 MEA, 6% O_2, 0.05 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.9	4.89	0.000119
1	4.9	4.89	0.000119
23	4.87	4.89	0.000119
47	4.89	4.89	0.000119
71	4.87	4.88	0.000119
95	4.89	4.88	0.000119
119	4.88	4.88	0.000119
			Average = 0.000119

Table A7 Run number 7: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.17	5.15	0.000491
23	5.12	5.14	0.000490
34.5	5.13	5.14	0.000489
47.5	5.12	5.13	0.000488
121.5	5.12	5.10	0.000485
193	5.08	5.06	0.000482
289	5	5.02	0.000477
			Average = 0.000486

Table A8 Run number 8: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.05 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.04	5.03	0.000143
24	5.02	5.03	0.000143
48	5.02	5.02	0.000143
72	5.04	5.02	0.000143
96	4.99	5.02	0.000143
122	5.02	5.01	0.000142
144	5	5.01	0.000142
168	5.02	5.01	0.000142
216	5	5	0.000142
			Average = 0.000143

Table A9 Run number 9: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.05 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.05	5.02	0.000776
11	5.02	5.01	0.000774
25	4.99	5	0.000773
35	4.97	5	0.000771
49	4.98	4.98	0.000770
59.5	4.98	4.97	0.000768
68.5	4.97	4.97	0.000767
94	4.98	4.95	0.000764
108	4.98	4.94	0.000763
137	4.78	4.91	0.000759
168	4.94	4.89	0.000756
185	4.84	4.88	0.000754
235	4.83	4.84	0.000748
282	4.81	4.80	0.000742
309	4.79	4.78	0.000739
336	4.79	4.76	0.000736
			Average = 0.00076007

Table A10 Run number 10: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.05 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.13	5.13	4.59263E-05
6	5.17	5.13	4.59238E-05
15	5.14	5.13	4.59201E-05

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
25	5.13	5.13	4.5916E-05
49	5.15	5.13	4.59061E-05
72	5.11	5.13	4.58967E-05
96	5.12	5.13	4.58868E-05
120	5.1	5.13	4.5877E-05
146	5.1	5.12	4.58663E-05
168	5.1	5.12	4.58573E-05
192	5.12	5.12	4.58474E-05
240	5.12	5.12	4.58277E-05
289	5.12	5.12	4.58076E-05
336	5.15	5.12	4.57884E-05
			Average = 4.58748E-05

Table A11 Run number 11: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.33 CO_2 loading, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.08	5.13	0.000445
3	5.17	5.13	0.000445
19	5.11	5.12	0.000444
34	5.14	5.11	0.000443
75	5.11	5.10	0.000442
110	5.07	5.08	0.000441
134	5.08	5.07	0.000440
159	5.06	5.06	0.000439
182	5.02	5.05	0.000438
239	5.03	5.02	0.000436
284	4.99	5	0.000434

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
336	5	4.98	0.000432
			Average = 0.000440

Table A12 Run number 12: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.33 CO_2 loading, 0.05 kmol/m^3 inhibitor UR-A, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.07	5.06	0.000380
12	5.11	5.05	0.000380
24	5.11	5.05	0.000380
48	4.99	5.04	0.000379
72	5.02	5.03	0.000378
96	4.93	5.02	0.000378
130	5.06	5.01	0.000377
168	4.95	5	0.000376
186	5	4.99	0.000375
207	4.95	4.98	0.000375
259.5	4.96	4.96	0.000373
336	4.98	4.93	0.000371
			Average = 0.000377

Table A13 Run number 13: 5 kmol/m^3 MEA, 6% O_2, 0.1 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.88	4.89	0.000227
4	4.92	4.89	0.000227
12	4.92	4.89	0.000227
33	4.88	4.89	0.000227
44	4.9	4.88	0.000227
56	4.81	4.88	0.000227
68	4.85	4.88	0.000226
81	4.9	4.88	0.000226
91.5	4.88	4.87	0.000226
101	4.88	4.87	0.000226
115.5	4.87	4.87	0.000226
140	4.84	4.86	0.000226
158	4.88	4.86	0.000225
168	4.86	4.86	0.000225
			Average = 0.000226

Table A14 Run number 14: 5 kmol/m^3 MEA, 6% O_2, 0.01 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.08	5.06	3.065E-05
2	5.08	5.06	3.06497E-05
25	5.09	5.06	3.06454E-05
49	5.04	5.06	3.06409E-05

72	4.97	5.06	3.06367E-05
94	5.07	5.05	3.06326E-05
120	5.06	5.05	3.06278E-05
146	5.05	5.05	3.06229E-05
168	5.04	5.05	3.06189E-05
192	5.04	5.05	3.06144E-05
240	5.07	5.05	3.06055E-05
336	5.06	5.05	3.05877E-05
			Average = 3.06277E-05

Table A15 Run number 15: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.3 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.97	4.98	0.000189
24	5.01	4.98	0.000188
39	4.97	4.98	0.000188
51	4.94	4.97	0.000188
68	4.97	4.97	0.000188
76	5.02	4.97	0.000188
90.5	4.94	4.97	0.000188
105	4.96	4.96	0.000188
128	4.93	4.96	0.000188
138	5.02	4.96	0.000188
148	4.93	4.96	0.000187
164.5	4.97	4.95	0.000187
168	4.93	4.95	0.000187
			Average = 0.000188

Table A16 Run number 16: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.1 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.06	5.04	8.05303E-05
15	5.06	5.04	8.0511E-05
27	5.03	5.04	8.04956E-05
44	5.05	5.04	8.04737E-05
66.5	5.01	5.04	8.04448E-05
81	4.99	5.04	8.04262E-05
104	5.04	5.03	8.03967E-05
114	5.05	5.03	8.03838E-05
124	5.01	5.03	8.0371E-05
140.5	5.03	5.03	8.03498E-05
144	5.07	5.03	8.03453E-05
			Average = 8.04298E-05

Table A17 Run number 17: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.06 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.08	5.08	0.000102
4	5.08	5.08	0.000102
24	5.14	5.07	0.000102
48	5.06	5.07	0.000102
72	5.05	5.07	0.000102
96	5.03	5.07	0.000102
145	5.01	5.06	0.000102
192	5.09	5.06	0.000102

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
240	5.04	5.05	0.000102
292	5.04	5.05	0.000102
336	5.07	5.04	0.000101
			Average = 0.000102

Table A18 Run number 18: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.03 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.04	5.01	0.000297
22	5.00	5	0.000297
70	4.96	4.99	0.000296
118	4.97	4.97	0.000295
207	4.97	4.95	0.000293
214	4.91	4.95	0.000293
334	4.93	4.91	0.000291
			Average = 0.000295

Table A19 Run number 19: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.01 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.90	4.86	4.66495E-06
7	4.91	4.86	4.66492E-06
26	4.80	4.86	4.66483E-06
54	4.83	4.86	4.66471E-06
65	4.83	4.86	4.66466E-06

Degradation time (h)	MEA concentration ($kmol/m^3$)		MEA degradation rate ($kmol/m^3.h$)
	Experimental	Predicted	
94	4.85	4.86	4.66453E-06
152	4.87	4.86	4.66427E-06
168	4.88	4.86	4.6642E-06
			Average = 4.66463E-06

Table A20 Run number 20: 5 $kmol/m^3$ MEA, 6% O_2, 6 ppm SO_2, 0.005 $kmol/m^3$ inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration ($kmol/m^3$)		MEA degradation rate ($kmol/m^3.h$)
	Experimental	Predicted	
0	4.94	5.02	0.000332
11	5.01	5.02	0.000332
25	5.05	5.01	0.000332
35	5.06	5	0.000332
49	4.96	5	0.000331
59.5	5.05	5	0.000331
68.5	5	5	0.000331
83.5	5.05	4.99	0.000331
94	5	4.99	0.000330
108	4.9	4.98	0.000330
159	5	4.97	0.000329
168	4.93	4.96	0.000329
			Average = 0.000331

Table A21 Run number 21: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.01 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.93	4.93	6.49383E-05
12.5	4.92	4.93	6.49276E-05
24.5	4.95	4.93	6.49174E-05
35	4.92	4.93	6.49084E-05
59.5	4.92	4.93	6.48875E-05
88	4.93	4.93	6.48631E-05
113	4.92	4.92	6.48418E-05
134	4.95	4.92	6.48238E-05
166	4.93	4.92	6.47965E-05
213	4.88	4.92	6.47564E-05
233	4.90	4.92	6.47394E-05
289	4.91	4.91	6.46916E-05
336	4.93	4.91	6.46516E-05
			Average = 6.48264E-05

Table A22 Run number 22: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.33 CO_2 loading, 0.01 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.98	5	7.39472E-05
2	5.07	5	7.3945E-05
12	5	5	7.39341E-05
21	5.01	4.99	7.39242E-05
65	5	4.99	7.38761E-05
100	4.93	4.99	7.38378E-05

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
134	4.98	4.99	7.38007E-05
161	4.93	4.98	7.37712E-05
186	4.93	4.98	7.37439E-05
235	4.98	4.98	7.36905E-05
264	5.04	4.98	7.36588E-05
299	5	4.97	7.36207E-05
			Average = 7.38125E-05

Table A23 Run number 23: 5 kmol/m^3 MEA, 6% O_2, 0.0025 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.98	4.95	8.37708E-05
12	4.95	4.95	8.37538E-05
33	4.93	4.95	8.3724E-05
56	4.91	4.94	8.36914E-05
68	4.91	4.94	8.36744E-05
81	4.91	4.94	8.3656E-05
91.5	5.03	4.94	8.36412E-05
101	4.96	4.94	8.36277E-05
140	4.86	4.94	8.35725E-05
168	4.98	4.93	8.35329E-05
			Average = 8.36645E-05

Table A24 Run number 24: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.1 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.04	4.99	0.001523
6	5.06	4.98	0.001521
19.5	4.92	4.96	0.001514
29	4.91	4.94	0.001510
42	4.86	4.92	0.001504
54	4.90	4.90	0.001499
73.5	4.83	4.87	0.001490
98	4.85	4.84	0.001479
118	4.79	4.81	0.001470
141	4.74	4.78	0.001459
148	4.81	4.77	0.001456
162	4.77	4.74	0.001450
168	4.75	4.74	0.001447
			Average = 0.001486

Table A25 Run number 25: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.005 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.09	5.07	0.000458
6	5.08	5.06	0.000458
19.5	5.10	5.06	0.000458
29	5.00	5.05	0.000457
42	5.05	5.05	0.000456
54	5.03	5.04	0.000456

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
73.5	5.00	5.03	0.000455
98	5.01	5.02	0.000454
141	4.98	5	0.000452
162	5.01	4.99	0.000451
168	5.02	4.99	0.000451
			Average = 0.000455

Table A26 Run number 26: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.0025 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.05	5.04	0.000109
18	5.07	5.03	0.000109
26	5.07	5.03	0.000109
40	5.11	5.03	0.000109
50	5.02	5.03	0.000109
66.5	4.85	5.03	0.000109
74.5	4.91	5.03	0.000109
88.5	5.10	5.03	0.000109
98.5	5.10	5.03	0.000109
113	4.99	5.02	0.000109
142.5	5.01	5.02	0.000109
160.5	5.01	5.02	0.000109
168	5.08	5.02	0.000109
			Average = 0.000109

Table A27 Run number 27: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.00125 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5.12	5.09	4.55308E-05
26	5.07	5.09	4.55202E-05
40	5.01	5.09	4.55145E-05
50	5.08	5.08	4.55104E-05
66.5	5.13	5.08	4.55037E-05
74.5	5.10	5.08	4.55005E-05
98.5	5.09	5.08	4.54907E-05
113	5.09	5.08	4.54848E-05
123	5.10	5.08	4.54807E-05
142.5	5.05	5.08	4.54728E-05
160.5	5.08	5.08	4.54655E-05
			Average = 4.54977E-05

Table A28 Run number 28: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.0025 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.91	4.88	9.05883E-05
24	4.89	4.88	9.05479E-05
48	4.90	4.88	9.05076E-05
72	4.80	4.87	9.04673E-05
96	4.88	4.87	9.0427E-05
121	4.83	4.87	9.03851E-05
144	4.90	4.87	9.03465E-05
216	4.85	4.86	9.02259E-05

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
264	4.88	4.86	9.01455E-05
336	4.85	4.85	9.00251E-05
			Average = 9.03666E-05

Table A29 Run number 29: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.33 CO_2 loading, 0.0025 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.9	4.89	0.000232
10	4.93	4.88	0.000232
24	4.91	4.88	0.000232
44	4.88	4.88	0.000232
54.5	4.78	4.87	0.000232
70.5	4.92	4.87	0.000232
82.5	4.86	4.87	0.000231
110	4.84	4.86	0.000231
139	4.92	4.86	0.000231
168	4.76	4.85	0.000230
216	4.79	4.84	0.000230
277.5	4.81	4.82	0.000229
307	4.86	4.82	0.000229
336	4.84	4.81	0.000229
			Average = 0.000231

Table A30 Run number 30: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 1 kmol/m^3 inhibitor UR-D, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.73	4.74	0.000215
6	4.73	4.74	0.000215
11	4.76	4.74	0.000215
34.5	4.75	4.73	0.000215
43	4.67	4.73	0.000215
57	4.71	4.73	0.000214
68	4.71	4.72	0.000214
82.5	4.78	4.72	0.000214
92	4.74	4.72	0.000214
107	4.73	4.72	0.000214
118	4.71	4.71	0.000214
155	4.68	4.71	0.000213
168	4.70	4.70	0.000213
			Average = 0.000214

Table A31 Run number 31: 5 kmol/m^3 MEA, 6% O_2, 6 ppm SO_2, 0.5 kmol/m^3 inhibitor UR-D, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	5	4.89	0.000205
11	4.83	4.89	0.000205
34.5	4.87	4.88	0.000205
43	4.94	4.88	0.000204
57	4.8	4.88	0.000204
68	4.87	4.88	0.000204

Degradation time (h)	MEA concentration ($kmol/m^3$)		MEA degradation rate ($kmol/m^3.h$)
	Experimental	Predicted	
82.5	4.84	4.87	0.000204
92	4.84	4.87	0.000204
133	4.91	4.86	0.000204
155	4.86	4.86	0.000204
168	4.88	4.86	0.000203
			Average = 0.000204

Table A32 Run number 32: 5 $kmol/m^3$ MEA, 6% O_2, 6 ppm SO_2, 0.025 $kmol/m^3$ inhibitor UR-D, and 120°C

Degradation time (h)	MEA concentration ($kmol/m^3$)		MEA degradation rate ($kmol/m^3.h$)
	Experimental	Predicted	
0	4.88	4.96	5.96882E-05
3	4.87	4.96	5.9686E-05
14	4.96	4.96	5.96781E-05
24	5.11	4.96	5.96709E-05
38.5	4.89	4.96	5.96605E-05
64	5.07	4.95	5.96422E-05
96	4.99	4.95	5.96192E-05
110.5	4.91	4.95	5.96088E-05
122	4.94	4.95	5.96006E-05
135	4.99	4.95	5.95913E-05
146	4.98	4.95	5.95834E-05
157	4.94	4.95	5.95755E-05
168	4.86	4.95	5.95676E-05
			Average = 5.96286E-05

Table A33 Run number 33: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.05 kmol/m^3 inhibitor UR-A blend with 0.01 kmol/m^3 inhibitor UR-B, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.96	4.94	1.43849E-05
12.5	4.91	4.94	1.43844E-05
24.5	4.95	4.94	1.43839E-05
35	5.00	4.94	1.43835E-05
59.5	4.95	4.94	1.43824E-05
88	4.98	4.94	1.43813E-05
113	4.89	4.94	1.43802E-05
134	4.88	4.94	1.43793E-05
166	4.89	4.94	1.4378E-05
213	4.99	4.94	1.4376E-05
289	4.96	4.94	1.43728E-05
336	4.94	4.93	1.43709E-05
			Average = 1.43798E-05

Table A34 Run number 34: 5 kmol/m^3 MEA, 6% O_2, 196 ppm SO_2, 0.05 kmol/m^3 inhibitor UR-A blend with 0.0025 kmol/m^3 inhibitor UR-C, and 120°C

Degradation time (h)	MEA concentration (kmol/m^3)		MEA degradation rate (kmol/m^3.h)
	Experimental	Predicted	
0	4.96	4.91	0.000452
7	4.88	4.91	0.000451
26	4.88	4.90	0.000451
54	4.84	4.88	0.000449
65	4.85	4.88	0.000449
74	4.89	4.87	0.000449
94	4.89	4.87	0.000448

Degradation time (h)	MEA concentration ($kmol/m^3$)		MEA degradation rate ($kmol/m^3.h$)
	Experimental	Predicted	
114	4.89	4.86	0.000447
122	4.91	4.85	0.000447
138	4.80	4.85	0.000446
152	4.80	4.84	0.000445
162	4.87	4.84	0.000445
168	4.82	4.83	0.000445
			Average = 0.000448

Appendix B Summary Operating Conditions and Degradation Rates of Oxidative Degradation Inhibitors for MEA Experiments

Table B1 Operating conditions and degradation rates of oxidative degradation of MEA with inhibitor UR-A

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-A ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
1	7	100	0	0	0	120	123.5170	2.3072	1.51E-03
2	7	100	0	0	0.1	120	211.0743	2.3392	3.88E-03
3	5	6	0	0	0	120	4.4810	0.2859	2.13E-06
4	5	6	0	0	0.3	120	12.8400	0.7340	1.79E-05
5	5	6	0	0	0.1	120	6.5360	0.4829	2.94E-06
6	5	6	0	0	0.05	120	1.1920	0.1894	1.35E-07
7	5	6	6	0	0	120	4.7350	0.3258	4.65E-06
8	5	6	6	0	0.05	120	1.4257	0.2152	2.86E-07
9	5	6	196	0	0	120	7.6007	0.5481	1.28E-05
10	5	6	196	0	0.05	120	0.4588	0.2626	3.84E-08
11	5	6	196	0.33	0	120	4.3981	0.3779	4.29E-06

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-A ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
12	5	6	196	0.33	0.05	120	3.7675	0.7786	2.99E-06

Table B2 Operating conditions and degradation rates of oxidative degradation of MEA with inhibitor UR-B

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-B ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
13	5	6	0	0	0.1	120	2.2631	0.4160	0.36
14	5	6	0	0	0.01	120	0.3063	0.4308	0.44
15	5	6	6	0	0.3	120	1.8787	0.4990	3.90E-07
16	5	6	6	0	0.1	120	0.8043	0.3902	6.59E-08
17	5	6	6	0	0.06	120	1.0186	0.4872	2.42E-07
18	5	6	6	0	0.03	120	2.9454	0.3887	0.24
19	5	6	6	0	0.01	120	0.0466	0.6400	2.83E-10
20	5	6	6	0	0.005	120	3.3096	0.8241	1.17E-06

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-B ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
21	5	6	196	0	0.01	120	0.6483	0.2641	9.36E-08
22	5	6	196	0.33	0.01	120	0.7381	0.6359	1.17E-07

Table B3 Operating conditions and degradation rates of oxidative degradation of MEA with inhibitor UR-C

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-C ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
23	5	6	0	0	0.0025	120	0.8367	0.7674	7.56E-08
24	5	6	6	0	0.1	120	14.8624	0.7325	2.77E-05
25	5	6	6	0	0.005	120	4.5498	0.4772	2.54E-06
26	5	6	6	0	0.0025	120	1.0906	1.1324	1.29E-07
27	5	6	6	0	0.00125	120	1.7703	0.2980	3.12E-07
28	5	6	196	0	0.0025	120	0.9037	0.5213	1.83E-07

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-C ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
29	5	6	196	0.33	0.0025	120	2.3090	0.8117	1.24E-06

Table B4 Operating conditions and degradation rates of oxidative degradation of MEA with inhibitor UR-D

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	CO_2 loading ($molCO_2/molMEA$)	UR-D ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
30	5	6	6	0	1	120	2.1424	0.4460	5.30E-07
31	5	6	6	0	0.5	120	2.0416	0.8613	4.79E-07
32	5	6	6	0	0.025	120	0.5963	1.1768	4.43E-08

Table B5 Operating conditions and degradation rates of oxidative degradation of MEA with blended inhibitors

Run no.	MEA ($kmol/m^3$)	O_2 (%)	SO_2 (ppm)	Blended Inhibitors ($kmol/m^3$)	Temperature (^oC)	Degradation Rate ($kmol/m^3.h)x10^{-4}$	%AAD	STDEV
33	5	6	196	0.05 UR-A, 0.01 UR-B	120	0.1438	0.6646	4.60E-09
34	5	6	196	0.05 UR-A, 0.0025 UR-C	120	4.4791	0.6619	2.39E-06

Appendix C The sample plots of HPLC technique

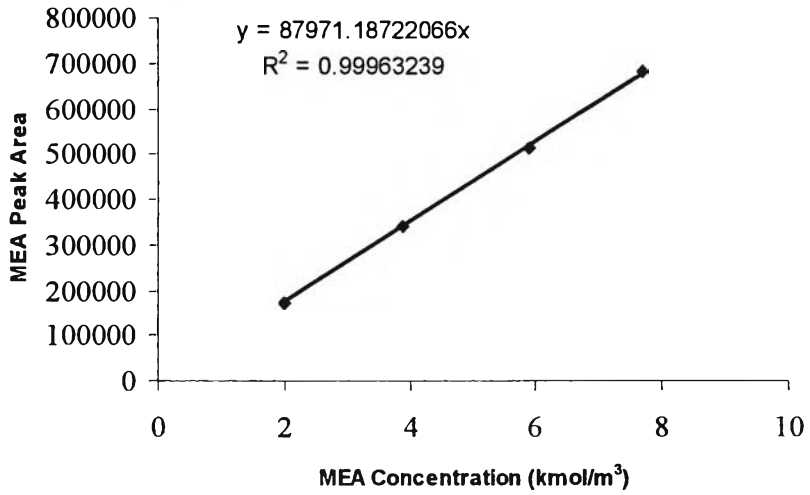

Figure C1 MEA calibration curve

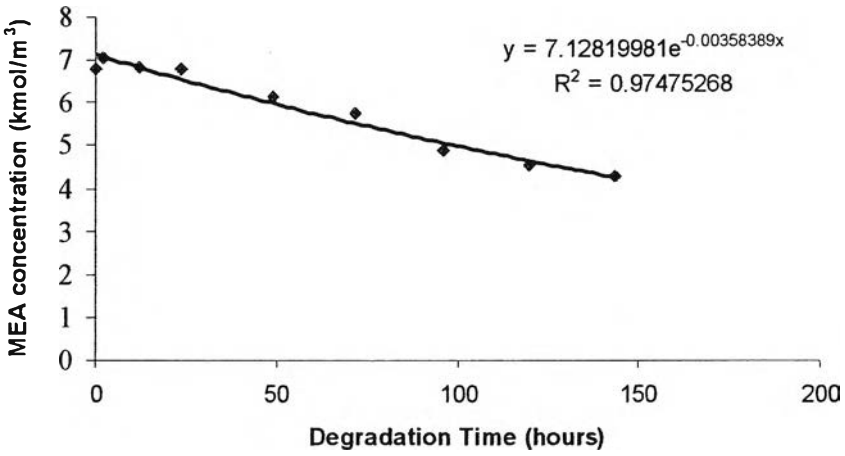

Figure C2 MEA concentration-time plot

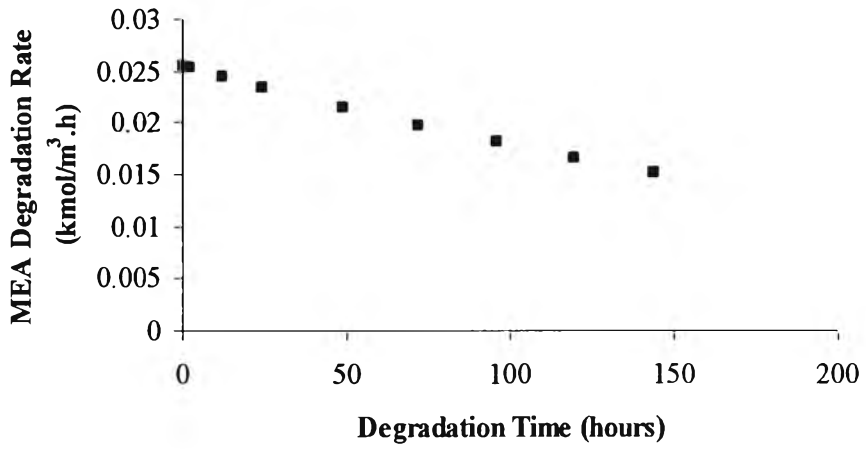

Figure C3 MEA degradation rate-time plot

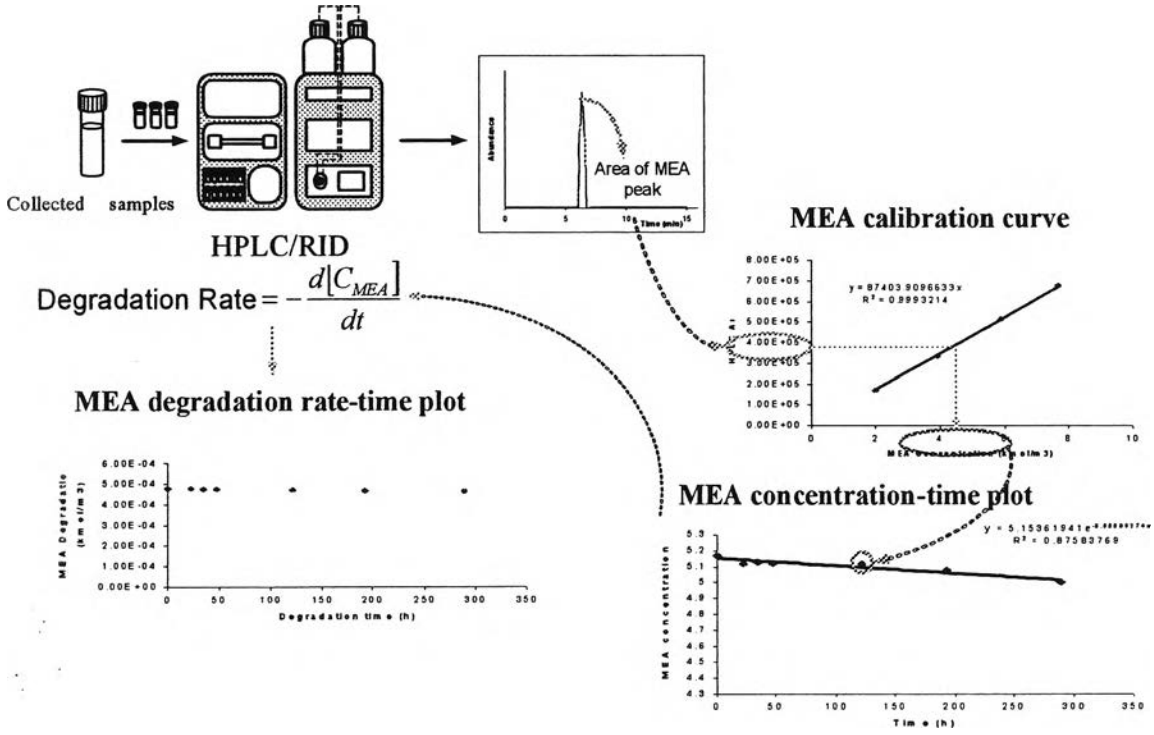

Figure C4 Schematic of the degradation analysis

CURRICULUM VITAE

Name: Mr. Purachet Pitipuech

Date of Birth: June 24, 1981

Nationality: Thai

University Education:

2000-2004 Bachelor's Degree of Chemical Engineering, Faculty of Engineering, Mahidol University, Bangkok, Thailand

Proceedings:

1. Pitipuech, P., Supap, T., Idem, R., Tontiwachwuthikul, P., and Saiwan, C. (2007, June 25-28) Study on degradation inhibitors for amine based solvents for CO_2 absorption from power plant flue gases. Proceedings of the 2nd ICAPP 2007, Bangkok, Thailand.

Conference:

1. Pitipuech, P., Supap, T., Idem, R., Tontiwachwuthikul, P., and Saiwan, C. (2007, October 28-31) Development of Degradation Inhibitor Additives for Amines during the Capture of Carbon Dioxide from Power Plant Flue Gases at the 57th Canadian Chemical Engineering Conference, Edmonton, Alberta, Canada
2. Kladkaew, N., Pitipuech, P., Supap, T, Idem, R., Tontiwachwuthikul, P., and Saiwan, C. (2007, October 28-31) Studies of SO_2 Induced Corrosion During CO_2 Capture from Coal Fired Power Plant Flue Gases Using Aqueous MEA at the 57th Canadian Chemical Engineering Conference, Edmonton, Alberta, Canada