7.0 APPENDIX

7.1 Tables 1 Through 15

7.2 Figures 1 Through 147

TABLE 1

SHIFTED METHANATION FEED, CALCULATED EQUILIBRIUM, AND TYPICAL PRODUCT GAS COMPOSITIONS

Component	Feed; v/o	Equilibrium[1] Calculated Effluent; v/o	Typical Effluent
Hydrogen	13.30	2.07	1.77
Argon	5.17	5.84	5.92
Nitrogen	73.96	83.54	84.20
Methane	3.39	8.11	7.86
Carbon Monoxide	3.72	0.04	0.01
Carbon Dioxide	0.46	0.40	0.23
	100.00	100.00	99.99

(1) Dry Basis; at 1000 psig and 900°F

TABLE 2

LISTING OF NICKEL CATALYSTS

Manufacturer	Catalyst	Nominal Composition	Reactor
United Catalyst Inc.	G87-S 1/4 x 1/8 Spheres	40% Ni; calcium aluminate	1
United Catalyst Inc.	C150-4-03 1/8 x 1/8 Tablets	60% Ni; alumina	2
Katalco Corp.	CRG-F 1/8 x 1/8 Tablets	60% Ni; proprietary	3
Harshaw	Ni-3210 Lot #133 3/16 Tablets	35% Ni; proprietary	4
Harshaw	Ni-0104 Lot #972 1/8 Tablets	60% Ni; kieselguhr	5

TABLE 3

NOMINAL REACTION CONDITIONS

Test Length, Hr	100	300	600	1,200
Maximum Temperature, ^{o}F	900	900	900	900
Total Pressure, psi	1,000	1,000	1,000	1,000
Space Velocity, Hr^{-1}	10,000	10,000	10,000	10,000
Gas Type*	Shifted, methanation feed gas (63% H_2, 19% CO, 2% CO_2. 16% CH_4			
Steam Addition, Mol%	0; 15	0; 15	0; 15	0; 15

*Gas will be diluted with 4 parts N_2

TABLE 4

CATALYST CHARACTERISTICS

Scan Description	Catalyst*	Surface Area; m^2/g	Pore Volume o 29.2A; cc/g	%C	XRD Ni Surface Area; m^2/g
Virgin Reduced	A	72.0	0.49	0.18	19.7
	B	174.0	0.21	2.55	37.0
	C	134.0	0.29	2.33	23.4
	D	159.0	0.14	3.53	74.0
	E	138.0	0.14	4.10	37.0
100 Hour w/o Steam	A	32.0	0.57	1.18	14.4
	B	52.0	0.38	2.78	15.4
	C	66.0	0.34	2.70	34.0
	D	61.0	0.16	4.61	47.0
	E	75.0	0.21	4.63	58.0
100 Hour with Steam	A	32.0	0.58	1.68	14.5
	B	111.0	0.34	4.18	47.4
	C	107.0	0.32	2.75	54.5
	D	131.0	0.19	5.33	120.0
	E	92.7	0.17	4.09	77.3
300 Hour w/o Steam	A	36.0	0.57	1.20	18.0
	B	64.0	0.34	2.80	32.1
	C	53.0	0.24	1.38	36.8
	D	139.0	0.17	5.37	77.3
	E	89.0	0.14	5.12	49.0
300 Hour with Steam	A	27.5	0.59	1.51	18.0
	B	89.5	0.33	4.16	54.0
	C	91.5	0.34	3.47	53.0
	D	67.0	0.20	6.29	47.0
	E	81.0	0.18	5.39	47.4
600 Hour w/o Steam	A	36.0	0.58	1.62	14.3
	B	83.0	0.34	4.42	33.5
	C	143.0	0.59	3.26	36.6
	D	82.0	0.23	5.81	67.6
	E	73.0	0.34	4.10	61.5

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 4 (CONTINUED)

CATALYST CHARACTERISTICS

Scan Description	Catalyst*	Surface Area; m^2/g	Pore Volume o 29.2A; cc/g	%C	XRD Ni Surface Area; m^2/g
1200 Hour w/o Steam	A	40.0	0.60	1.27	14.5
	B	60.0	0.36	3.30	33.7
	C	67.0	0.36	3.62	33.7
	D	74.0	0.27	5.15	54.5
	E	56.0	0.20	5.48	47.4
1200 Hour with Steam	A	14.0	0.38	1.13	3.6
	B	30.6	0.34	2.23	19.7
	C	35.0	0.34	2.87	16.4
	D	49.7	0.23	2.47	37.8
	E	52.0	0.16	4.67	40.0

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 5

Virgin Reduced Catalyst

Catalyst *	XRD** Data
A	1. NiO (∿58%) MCS = 39 Å
	2. Ni (∿42%) MCS = 103 Å
	3. γ-Al_2O_3 MCS = 41 Å
	4. α-$Al_2O_3 \cdot H_2O$ (?)
B	1. NiO (∿79%) MCS = 40 Å
	2. Ni (∿21%) MCS = 27 Å
	3. C (Graphite) MCS = 582 Å
	4. α-$Al_2O_3 \cdot H_2O$ (?)
C	1. NiO (∿80%) MCS = 31 Å
	2. Ni (∿20%) MCS = 41 Å
	3. C (Graphite) MCS > 1323 Å
D	1. Ni MCS = 65 Å
	2. CaO MCS = 817 Å
	3. C (Graphite) MCS > 1000 Å
E	1. NiO (∿56%) MCS = 34 Å
	2. Ni (∿44%) MCS = 58 Å
	3. C (Graphite) MCS > 1000 Å

*Catalyst A - UCI-87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**MCS = Mean Crystallite Size

TABLE 5 (CONTINUED)

100 Hour w/o Steam Test

Catalyst*	XRD** Data
A	1. Ni MCS = 335 Å
	2. γ -Al_2O_3 MCS = 67 Å
	3. α -Al_2O_3 (10%) MCS > 2000 Å
	4. $CaCO_3$ MCS = 1428 Å
	5. $12CaO \cdot 7Al_2O_3$ (?)
B	1. Ni MCS = 312 Å
	2. γ -Al_2O_3 MCS = 58 Å
	3. C (Graphite) MCS = 1323 Å
	4. α -$Al_2O_3 \cdot H_2O$ (?)
C	1. Ni MCS = 143 Å
	2. γ -Al_2O_3 MCS = 45 Å
	3. C (Graphite) MCS = 1003 Å
	4. α -$Al_2O_3 \cdot H_2O$ (?)
D	1. Ni MCS = 84 Å
	2. C (Graphite) MCS > 1000 Å
	3. $CaCO_3$ (?)
E	1. Ni MCS = 83 Å
	2. $CaCO_3$ MCS = 800 Å
	3. C (Graphite) MCS > 1000 Å

*Catalyst A - UCI-87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

** MCS = Mean Crystallite Size

TABLE 5 (CONTINUED)

100 Hour with Steam Test

Catalyst*	XRD** Data
A	1. Ni MCS = 330 Å
	2. γ-Al_2O_3 MCS = 68 Å
	3. α-Al_2O_3 (<10%) MCS > 2000 Å
	4. $CaCO_3$ MCS = 1428 Å
B	1. Ni MCS = 101 Å
	2. γ-Al_2O_3 MCS = 51 Å
	3. C (Graphite) MCS > 2000 Å
C	1. Ni MCS = 88 Å
	2. γ-Al_2O_3 MCS = 47 Å
	3. C (Graphite) MCS > 2000 Å
D	1. Ni MCS = 40 Å
	2. $CaCO_3$ MCS = 1285 Å
	3. C (Graphite) MCS > 2000 Å
	4. α-Al_2O_3 (?)
E	1. Ni MCS 62 Å
	2. C (Graphite) MCS = 1136 Å

*Catalyst A - UCI-87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**MCS = Mean Crystallite Size

TABLE 5 (CONTINUED)

300 Hour with Steam Test

Catalyst*	XRD** Data
A	1. Ni MCS = 268 Å
	2. γ-Al_2O_3 MCS = 63 Å
	3. α-Al_2O_3 (<10%) MCS > 2000 Å
	4. $CaCO_3$ MCS = 1397 Å
B	1. Ni MCS = 89 Å
	2. γ-Al_2O_3 MCS = 53 Å
	3. C (Graphite) MCS = 780 Å
C	1. Ni MCS = 90 Å
	2. γ-Al_2O_3 MCS = 63 Å
	3. C (Graphite) MCS = 980 Å
D	1. Ni MCS = 100 Å
	2. $CaCO_3$ MCS = 980 Å
	3. C (Graphite) MCS = 1250 Å
E	1. Ni MCS = 101 Å
	2. C (Graphite) MCS = 1600 Å

*Catalyst A - UCI-87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**MCS = Mean Crystallite Size

TABLE 5 (CONTINUED)

300 Hour w/o Steam Test

Catalyst *	XRD** Data
A	1. Ni MCS = 268 Å
	2. γ -Al_2O_3 = 71 Å
	3. α -Al_2O_3 > 2000 Å
	4. $CaCO_3$ MCS = 1385 Å
	5. 12 $CaO \cdot 7Al_2O_3$ (?)
B	1. Ni (~60%) MCS = 90 Å
	2. NiO (~40%) MCS = 43 Å
	3. C (Graphite) MCS = 1380 Å
C	1. Ni (~72%) MCS = 94 Å
	2. NiO (~28%) MCS = 39 Å
	3. C (Graphite) MCS = 980 Å
D	1. Ni MCS = 62 Å
	2. $CaCO_3$ MCS = 1120 Å
	3. C (Graphite) MCS = 870 Å
E	1. Ni MCS = 98 Å
	2. C (Graphite) MCS > 2000 Å

*Catalyst A - UCI-87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**MCS = Mean Crystallite Size

TABLE 5 (CONTINUED)

600 Hour Without Steam Test

Catalyst*	XRD Data**
A	1. Ni MCS = 335 Å
	2. γ-Al_2O_3 MCS = 56 Å
	3. $CaCO_3$ MCS = >2000 Å
	4. α-Al_2O_3 (?)
	5. $12CaO \cdot 7Al_2O_3$
B	1. Ni MCS = 143 Å
	2. α-Al_2O_3 MCS = 52 Å
	3. C (Graphite) MCS = 1001 Å
C	1. Ni MCS = 131 Å
	2. α-Al_2O_3 MCS = 44 Å
	3. C (Graphite) MCS = 510 Å
	4. $CaCO_3$ MCS = >2000 Å
D	1. Ni MCS = 71 Å
	2. $CaCO_3$ MCS = >2000 Å
	3. C (Graphite) MCS = >2000 Å
E	1. Ni MCS = 78 Å
	2. $CaCO_3$ MCS = >2000 Å
	3. C (Graphite) MCS = >2000 Å
	4. $Ni_3(OH)_4Si_2O_5$ (?)
	5. SiO_2 (α-quartz) (?)
	6. SiO_2 Al_2O_3 (?)

*A - UCI-G87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**Mean Crystallite Size

TABLE 5 (CONTINUED)

600 Hour With Steam Test

Catalyst*	XRD**
A	1. Ni MCS = 264 Å
	2. $CaCO_3$ MCS = >2000 Å
B	1. Ni MCS = 192 Å
	2. δ-Al_2O_3 MCS = 91 Å
	3. C (Graphite) MCS = 1320 Å
C	1. Ni MCS = 247 Å
	2. δ-Al_2O_3 MCS = 94 Å
	3. C (Graphite) MCS = 1320 Å
D	1. Ni MCS = 114 Å
	2. $CaCO_3$ MCS > 2000 Å
	3. C (Graphite) MCS > 2000 Å
E	1. Ni MCS = 148 Å
	2. δ-Al_2O_3 MCS = 87 Å
	3. C (Graphite) MCS = 1020 Å

*A - UCI-G87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**MCS = Mean Crystallite Size

TABLE 5 (CONTINUED)

1200 Hour w/o Steam Test

Catalyst*	XRD Data**
A	1. Ni MCS = 330 Å
	2. γ-Al_2O_3 MCS = 57 Å
	3. $CaCO_3$ MCS > 2000 Å
	4. α -Al_2O_3 MCS > 2000 Å
	5. 12 CaO·7 Al_2O_3 (?)
B	1. Ni MCS = 143 Å
	2. γ -Al_2O_3 MCS = 64 Å
	3. C (Graphite) MCS > 2000 Å
C	1. Ni MCS = 143 Å
	2. γ -Al_2O_3 MCS = 54 Å
	3. C (Graphite) MCS = 1000 Å
	4. $CaCO_3$ MCS > 2000 Å
D	1. Ni MCS = 88 Å
	2. $CaCO_3$ MCS > 2000 Å
	3. C (Graphite) MCS > 2000 Å
E	1. Ni MCS = 101 Å
	2. $CaCO_3$ MCS > 2000 Å
	3. C (Graphite) MCS > 2000 Å

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw - Ni-3210
E = Harshaw - Ni-0104

**Mean Crystallite Size

TABLE 5 (CONTINUED)

1200 Hour With Steam Test

Catalyst*	XRD Data**
A	1. Ni MCS = 1322 Å
	2. $CaCO_3$ MCS = >2000 Å
B	1. Ni MCS = 244 Å
	2. δAl_2O_3 (distorted) MCS = 97 Å
	3. C (Graphite) MCS = 1320 Å
C	1. Ni MCS = 292 Å
	2. γ-Al_2O_3 (~85%) MCS = 66 Å
	3. α-Al_2O_3 (~15%) MCS = >2000 Å
	4. C (Graphite) MCS = >2000 Å
D	1. Ni MCS = 127 Å
	2. $CaSiO_3$ MCS = >2000 Å
	3. C (Graphite) MCS = >2000 Å
	4. $CaCO_3$ MCS = >2000 Å
E	1. Ni MCS = 120 Å
	2. $CaCO_3$ MCS = >2000 Å
	3. C (Graphite) MCS = >2000 Å
	4. $Ni_3(OH)_4Si_2O_5$ (?)
	5. SiO_2 (α-quartz) (?)

*A - UCI-G87-S
B - UCI-C150-4-03
C - Katalco CRG-F
D - Harshaw Ni-3210
E - Harshaw Ni-0104

**mean crystallite size

TABLE 6

INCREASE IN NICKEL CRYSTALLITE SIZE (Å) WITH TIME

Catalyst*	Steam Level (Mol %)	Scan Description: Virgin Reduced	100 Hour	300 Hour	600 Hour	1200 Hour
A	0	103	335	268	335	330
	15	---	330	268	264	1322
B	0	27	312	90	143	143
	15	---	101	89	192	244
C	0	41	143	94	131	143
	15	---	88	90	247	292
D	0	65	84	62	71	88
	15	---	40	100	114	127
E	0	58	83	98	78	101
	15	---	62	101	148	120

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 7

DECREASE IN NICKEL SURFACE AREA (m^2/g) WITH TIME

Catalyst*	Steam Level (Mol %)	Scan Description: Virgin Reduced	100 Hour	300 Hour	600 Hour	1200 Hour
A	0	19.7	14.4	18.0	14.3	14.5
	15	---	14.5	18.0	18.2	3.6
B	0	37.0	15.4	32.1	33.5	33.7
	15	---	47.4	54.0	25.0	19.7
C	0	23.4	34.0	36.8	36.6	33.7
	15	---	54.5	53.0	19.4	16.4
D	0	74.0	47.0	77.3	67.6	54.5
	15	---	120.0	47.0	42.1	37.8
E	0	37.0	58.0	49.0	61.5	47.4
	15	---	77.3	47.4	32.4	40.0

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 8

DECREASE IN CATALYST SURFACE AREA (m^2/g) WITH TIME

Catalyst*	Steam Level (Mol %)	Scan Description: Virgin Reduced	100 Hour	300 Hour	600 Hour	1200 Hour
A	0	72.0	32.0	36.0	36.0	40.0
	15	---	32.0	27.5	16.7	14.0
B	0	174.0	52.0	64.0	83.0	60.0
	15	---	111.0	89.5	45.0	30.6
C	0	134.0	66.0	53.0	143.0	67.0
	15	---	107.0	91.5	41.0	35.0
D	0	159.0	61.0	139.0	82.0	74.0
	15	---	131.0	67.0	48.0	49.7
E	0	138.0	75.0	89.0	73.0	56.0
	15	---	92.0	81.0	35.0	52.0

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 9

INCREASE IN PORE VOLUME (cc/g) WITH TIME

Catalyst*	Steam Level (Mol %)	Scan Description: Virgin Reduced	100 Hour	300 Hour	600 Hour	1200 Hour
A	0	0.49	0.57	0.57	0.58	0.60
	15	---	0.58	0.59	0.58	0.38
B	0	0.21	0.38	0.34	0.34	0.36
	15	---	0.34	0.33	0.34	0.34
C	0	0.29	0.34	0.24	0.59	0.36
	15	---	0.32	0.34	0.36	0.34
D	0	0.14	0.16	0.17	0.23	0.27
	15	---	0.19	0.20	0.22	0.23
E	0	0.14	0.21	0.14	0.34	0.20
	15	---	0.17	0.18	0.15	0.16

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 10

INCREASE IN CARBON CONTENT (WT%) WITH TIME

Catalyst*	Steam Level (Mol %)	Scan Description: Virgin Reduced	100 Hour	300 Hour	600 Hour	1200 Hour
A	0	0.18	1.18	1.20	1.62	1.27
	15	---	1.68	1.51	1.10	1.13
B	0	2.55	2.78	2.80	4.42	3.30
	15	---	4.18	4.16	3.20	2.23
C	0	2.33	2.70	1.38	3.26	3.62
	15	---	2.75	3.47	2.90	2.87
D	0	3.53	4.61	5.37	5.81	5.15
	15	---	5.33	6.29	4.30	2.47
E	0	4.10	4.63	5.12	4.10	5.48
	15	---	4.09	5.39	5.00	4.67

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 11

CHANGE WITH CRUSH STRENGTH (Kg) WITH TIME

Catalyst*	Steam Level (Mol %)	Scan Description: Virgin Reduced	100 Hour	300 Hour	600 Hour	1200 Hour
A	0	10,818	4716	4200	3436	3312
	15	---	4241	2960	3322	1562
B	0	7,753	1115	1141	935	1031
	15	---	1167	1439	463	444
C	0	2,628	2088	2463	1629	1438
	15	---	2033	902	1102	427
D	0	6,101	3325	5742	5464	9775
	15	---	6460	8348	6128	6965
E	0	4,693	7312	2809	3208	3740
	15	---	3620	3930	2549	3161

*Catalyst A = UCI-G87-S
B = UCI-C150-4-03
C = Katalco CRG-F
D = Harshaw Ni-3210
E = Harshaw Ni-0104

TABLE 12

Characteristics of UCI Catalyst C150-4-03

During Regeneration Test Scans

Description	Total Hours On Stream	Surface Area; m^2/g	Pore Volume o >29.2 A;cc/g	%C	XRD Ni Surface Area; m^2/g
Cycle 1	300	64.0	0.34	3.6	30.6
Regeneration 1		--	--	1.7	--
Cycle 2	600	57.0	0.36	2.3	23.2
Regeneration 2		--	--	1.8	--
Cycle 3	900	55.0	0.38	2.4	25.0
Regeneration 3		--	--	1.7	--
Cycle 4	1200	51.0	0.36	2.4	25.0

TABLE 13

XRD Data For Regeneration Tests
Using UCI Catalyst C150-4-03

Cycle	Total Hours On Stream	XRD Data*
1	300	1. Ni MCS = 157 Å 2. δ-Al_2O_3 MCS = 58 Å 3. C (Graphite) MCS = 1320 Å
2	600	1. Ni MCS = 207 Å 2. δ-Al_2O_3 MCS = 64 Å 3. C (Graphite) MCS = 860 Å
3	900	1. Ni MCS = 192 Å 2. δ-Al_2O_3 MCS = 70 Å 3. C (Graphite) MCS = 807 Å
4	1200	1. Ni MCS = 192 Å 2. δ-Al_2O_3 MCS = 94 Å 3. C (Graphite) MCS > 2000 Å

*MCS = Mean Crystallite Size

TABLE 14

COMPONENT SUMMARY OF INSTALLED COST FOR
COLD-FLOW HYDRODYNAMIC UNIT

		Cost; $ (3rd Quarter, 1981)
1.	Purchased Equipment	89,460
2.	Equipment Setting	4,500
3.	Piping	73,800
4.	Steel	5,400
5.	Instrumentation	42,420
6.	Electrical	16,100
7.	Paint	900
	Total Field Cost	232,580
	Engineering	36,000
	Total	268,580

TABLE 15

PILOT PLANT CONSTRUCTION SCHEDULE