MASTER

SULFUR RESISTANT METHANATION CATALYSTS

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OBJECTIVE

The objective of this program is to study catalyst compositions in an effort to develop a sulfur resistant methanation catalyst for the methanation stage of a coal to SNG process.

In the processes to convert coal to a substitute natural gas the coal is first gasified by the reaction of coal with oxygen and steam at high temperature and moderate to high pressure to produce a synthesis gas consisting primarily of methane, hydrogen, carbon monoxide and carbon dioxide. The gas produced is a low BTU gas and carbon monoxide shift conversion is proposed to adjust the H_2 to CO ratio for subsequent hydrogenation of carbon monoxide to methane to produce a high BTU substitute natural gas.

Practically all of the methanation schemes will employ nickel catalyst for methanation. Since all coals contain some sulfur, a major disadvantage to the nickel catalysts are their susceptibility to sulfur poisoning. An operational upset could result in the premature loss of a catalyst charge.

The development of a sulfur tolerant or sulfur resistant catalyst would eliminate the loss of catalyst and could result in more flexibility and reduced operating cost in the sulfur adsorbent system. A study of catalyst compositions is being conducted to determine if a sulfur resistant methanation catalyst can be developed that would offer these process advantages.

SCOPE OF WORK

In order to study catalyst composition a series of experimental catalysts are being prepared and tested with a feed gas containing H_2S which is typical of the current methanation schemes for this process. These catalysts will consist of a metal, metal oxide or metal sulfide, or a combination of metals on various supports.

In all, approximately fifty catalysts will be prepared (Tasks 1 - 4, see Table I) consisting of (1) a single metal oxide on an alumina support, (2) metal oxide combinations on an alumina support, (3) selected metal oxide compositions on a silica support or a magnesium silicate support, and (4) variations in metal oxide ratios or method of preparation on selected metal oxide combinations. These catalyst samples will be characterized both chemically and physically by obtaining such properties as metal oxide, surface area and crush strength.

The catalysts will be pretreated by reducing or sulfiding and tested (Task 5) with a feed gas composition and at conditions typical of the various methanation schemes. On each test the operating conditions and analyses of the inlet and outlet gas composition will be recorded.

Selected catalysts will be run for longer periods with an eventual three month life test (Task 6) on the most active catalyst.

TABLE I

Task 1	Preparation of single metal oxide catalysts on alumina support.
Task 2	Preparation of metal oxide combination catalysts on alumina support.
Task 3	Preparation of catalysts of selected metal oxide combinations from Tasks 1 and 2 on SiO_2 and Mg SiO_3 support.
Task 4	Preparation of catalysts varying the metal ratios and/or method of preparation on selected combinations from Tasks 1, 2, or 3.
Task 5	Activity testing of catalysts from Tasks 1 - 4 at typical conditions for SNG methanation with H_2S in the feed gas.
Task 6	Three month life test on the most promising catalyst.

SUMMARY

Fifty-two activity tests have been completed on forty-five different catalyst compositions which were studied as sulfur-resistant methanation catalysts. A maximum conversion of carbon monoxide to methane of 84% was achieved at one point with nickel and chromium on magnesium silicate. This catalyst also demonstrated a reproducible conversion of 67% with very low steam and 3-10 ppm hydrogen sulfide in the feed gas. Tests during the past year have mainly involved catalysts which contain support material other than alumina.

In order to screen the catalysts as quickly as possible, extensive test condition variations were not performed, with the exception of a steam to gas variation study during one test. Several series of catalyst variations were prepared and tested, but most were found to be inactive. Significant methanation of 60-70% of the carbon monoxide has been achieved only with nickel and chromium on magnesium silicate and on magnesium aluminate.

The one year time extension has allowed us to match the contract expenditures more closely to the expected costs. As shown in Figure 1, the actual expenses after two years were \$67,558, and expected costs were \$80,000.

EXPERIMENTAL PROCEDURES AND EQUIPMENT

The methods and equipment for catalyst preparation and testing were explained in the last annual report. Current procedures are essentially the same, and reference can be made to the previous report for procedural details.

RESULTS AND DISCUSSION - TASKS 1 TO 4 - CATALYST PREPARATION

Tables II and V list all of the catalysts which have been tested under this contract. As the tables show, catalysts containing nickel, chromium, vanadium or a noble metal on various supports have been extensively tested over the past year. Most of these showed a significant decrease in surface area. Carbon formation on the catalysts has not occurred, as evidenced by the carbon analyses of used catalysts (about 3% graphite is already present in most new catalysts as a tabbing lubricant) and by the clean knock-out pot water from the unit. The sulfur analyses suggest that chromium is better than vanadium in prohibiting sulfur pickup by the catalyst, although this may be caused by the chromium content being higher than the vanadium content. Initially we thought that the adsorption

FIGURE 1

BAR GRAPH OF PROGRAM TASKS AND EXPENDITURES

Code for top bar graph:

Scheduled

Time Used

Code for bottom graph:

Expected Expenditures

Actual

of sulfur caused the loss of surface area. These results, however, show that the surface area decreases significantly even with low sulfur levels on the discharged catalysts. This suggests a physical or mechanistic effect on the surface area which is independent of the amount of sulfur present.

RESULTS AND DISCUSSION - TASK 5 - CATALYST TESTING

The test data is summarized for each test run in Table III. The last two columns show calculations which give an indication of catalyst activity. The percent of bed above the hot spot gives, as a percentage, the bed depth at which the maximum temperature of reaction occurred, as determined by taking a temperature profile. Thus, a value in this column indicates that only that part of the catalyst bed is being used to accomplish the reaction. The percent carbon monoxide conversion is based on the CO gas analyses, corrected by a factor based on the gas volume change caused by reaction.

Since the calculation of carbon monoxide conversion does not take into account whether shift or methanation was occurring, a mathematical method was developed to differentiate between the competing reactions. Calculations by this method are tabulated in Table IV; the method of calculation is presented as a footnote to that table.

The gas compositions are typical of the Lurgi coal gasification process with gas recycle at the methanator. Catalyst testing has proceeded with various recycle ratio gas compositions, and the data and results are tabulated in Tables III and IV.

The Ni-Cr and Fe-Cr catalysts were tested in Run 14 with several of the recycle gas compositions, as shown by the data in Table III. The total percent CO conversions are significant in many cases, but most of this is because of the shift reaction. A notable exception is the data acquired at hour 38 for the Fe-Cr catalyst. The calculations in Table IV, based on this data, show a large 44% conversion of CO to methane. Unfortunately, the catalyst did not maintain this activity.

Test 15 involved Ni-Cr catalysts supported by carriers other than alumina or chromia. The catalyst with magnesium oxide did not perform any better than several other catalyst compositions tested previously, but the calculations show that the catalyst with magnesium silicate had an improved methanation activity at high temperatures. More than 40% of the carbon monoxide is still unreacted, however.

The catalyst carriers were silica and magnesium aluminate in Test 16. The Ni-Cr-SiO₂ showed a suprisingly low shift conversion at 800°, but shift conversion took over again at the higher temperature. The Ni-Cr-MgAl₂O₄ showed a 36% methanation activity, which occurred at 800° and decreased significantly at 1150°F. Thus, the catalysts with MgSiO₃ or MgAl₂O₄ are the only ones to date which have shown a reproducible improvement in activity.

Test 17 involved a nickel-chromium catalyst prepared by a different method, and a retest of the Ni-Cr-Al₂O₃ catalyst, which was first tested in Run 6. The results were unexciting, although the alumina base catalyst did show a 29% methanation activity at one point.

Test 18 represented a slight departure from the objective in the testing of platinum on alumina and ruthenium on alumina catalyst preparations. The results from ruthenium were less than expected, but the platinum catalyst showed a 36% low temperature methanation activity.

The data summary for Run 19 shows that the Ni-Cr on MgAl₂O₄ and the Ni-Cr on MgSiO₃ catalysts were tested at 600°, 700°, and 800°F with the 500-850° recycle feed gas (Hours 4-13) and at 900°, 1000°, and 1100° with the 500-1150° recycle feed (Hours 17-69).

Table III has been expanded to include the hot spot obtained with each catalyst for each condition. A large temperature rise is another indication that more methanation is occurring. Hence the temperature profile also serves as a valuable indicator of the catalyst activity.

The data showed that the catalysts at 1000° or 1100°F were responding to lower steam to gas with an increased methanation activity. This was evident from the gas analyses and calculations, as well as from the temperature profiles, which showed a 50-120°F temperature rise. Therefore, they were tested further, at several temperatures with the raw feed gas composition (see Fifth Quarterly Report), in order to take advantage of the very low steam to gas ratio which is used with that gas composition. However, there was no evidence of catalyst activity with the raw feed gas, and carbon formation occurred with increased temperature. The catalysts were discharged, and new loadings of the same catalysts were tested.

The test results showed the best methanation activity of any catalysts to date. The Ni-Cr on MgAl₂O₄ demonstrated methanation conversions of 46% and 61% and the Ni-Cr on MgSiO₃ was even more impressive with conversions of 60%, 63%, and 84% both at 1100° and .2 S/G. This is in sharp contrast to all previous test results for which the best CO conversion to methane was 44% with the Fe-Cr catalyst.

Run 19 was continued after reloading the catalysts, which were Ni-Cr-MgSiO₃ and Ni-Cr-MgAl₂O₄, in order to acquire additional low steam data, as shown in Table III. For both catalysts the lower steam resulted in an increased methane production and lower hydrogen leakages. As the calculations in Table IV show, the lower steam eliminated the shift reaction, and in fact, promoted a reverse shift, which used up some of the hydrogen. For the last part of the test data was taken at a lower space velocity. We expected this change to cause an increase in the catalyst activity, but the data shows that there was not any effect.

Magnesium silicate tablets were impregnated with platinum and ruthenium and tested in Run 20. The lack of activity was disappointing, and this screening test was ended quickly.

The next three tests were done with normal steam to gas ratios. In Run 21, two new catalyst preparations, Ni on MgAl₂O₄ and on MgSiO₃, were tested. The data in Table III shows some methanation activity, as evidenced by the methane analyses, but the hydrogen and carbon monoxide analyses indicate a lot of shift reaction, too. Thus, the calculations in Table IV show only a 10-17% methanation activity.

The catalysts tested in Run 22 included one with an alpha alumina impregnated with nickel, in contrast to the earlier catalysts in which the nickel was coprecipitated with an amorphous alumina. The second catalyst tested contained nickel, chromium, and vanadium on MgSiO₃. The nickel on alumina catalyst was inactive, which demonstrates that alumina carrier of any type is not suitable for this application. The Ni-Cr-V catalyst showed 30-40% methanation activity at 1100°, but this is no more than several other catalysts have demonstrated before.

Catalysts with nickel and vanadium on magnesium silicate and Ni-Cr-V on magnesium aluminate were tested in Run 23. The hot spot location shows that the Ni-V catalyst used the whole catalyst bed for minimal methanation activity. The catalyst with nickel, chromium and vanadium demonstrated some methanation activity during the test (30%), but it was not as good as other previous results.

The catalysts tested in Run 24 contained nickel and vanadium on silica and on magnesium aluminate. As shown by Table III, the test was conducted with normal steam to gas levels and recycle gas compositions. The silica catalyst showed less shift reaction at the lower temperature, but with more steam with the feed gas. This is consistent with the results of test 16, in which the Ni-Cr-SiO₂ catalyst showed less shift

reaction at low temperature, high steam test conditions. This is also in contrast to most of the other catalysts tested, which usually displayed a greater shift reaction tendency at higher steam to gas ratios. Methanation activity was minimal, however.

The other catalyst tested in Run 24 was nickel and vanadium on magnesium aluminate. Shift activity decreased with higher temperature and lower steam to gas conditions, and an increase in methanation activity was also noted. The testing of this catalyst, moreover, allows us to construct the following short table, which includes data at 1100°F and normal steam to gas from Table V for two series of catalyst preparations:

<u>Catalyst</u>	<u>% CO to CH₄</u>	<u>Shift/Methanation Ratio</u>
Ni-MgSiO ₃	12.5	1.14
Ni-V-MgSiO ₃	9.2	2.59
Ni-Cr-MgSiO ₃	39.0 (61.7 retest)	0.39 (.02 retest)
Ni-Cr-V-MgSiO ₃	37.2	0.38
Ni-MgAl ₂ O ₄ (tabs)	13.6	0.97
Ni-Cr-MgAl ₂ O ₄ (tabs)	11.2 (53.7 retest)	2.57 (.10 retest)
Ni-V-MgAl ₂ O ₄ (approx. 1/2 tabs)	35.8	0.15
Ni-Cr-V-MgAl ₂ O ₄ (all 10-14 mesh granules)	29.7	0.59

We discovered after testing that dipping the magnesium aluminate carrier catalysts with vanadium solution caused a severe loss in crush strength and attrition resistance. Subsequent handling of the dipped tablets therefore caused them to break apart. Catalyst preparation by coprecipitation with vanadium would prevent this. However, the results for the magnesium aluminate catalysts are obscured by the particle size effect on the methanation activity. The calculations for the magnesium silicate catalysts on the other hand, show clearly that the activity is enhanced by chromium in the catalyst, and is not aided by vanadium.

All of the catalysts in Runs 25 and 26 showed minimal methanation activity, but testing of the platinum dipped catalysts provides the following table of calculations, again condensed from Table V:

<u>Catalyst</u>	<u>%CO to CH₄</u>		<u>Shift/Methanation Ratio</u>	
	800°	1100°	800°	1100°
Ni-MgSiO ₃	9.3	12.5	2.19	1.14
Ni-MgSiO ₃ /Pt	12.9	2.5	2.53	4.24
1-1 Ni-Cr	9.8	6.2	4.80	4.68
1-1 Ni-Cr/Pt	6.2	5.1	5.92	4.04

As shown by this table, methanation activity at either test condition is not improved by the presence of platinum at the 0.1% level.

Although significant methanation activity has been displayed by some of these experimental catalysts, it is important to note that this activity has only been achieved when testing at 1100°F. Catalyst activity at this temperature may be sufficient for a first stage methanator. However, the production of a high BTU synthetic natural gas, compatible with pipeline gas, will require a catalyst which has high methanation at low temperatures, 700°F for example, since the methane equilibrium is more favorable at lower temperatures.

CONCLUSIONS

1. Ni-Cr-MgSiO₃ and Ni-Cr-MgAl₂O₄ show the best methanation activity of all catalysts tested, at 1100°F.
2. The work thus far has not resulted in the development of a catalyst with good activity at low temperatures.
3. Chromium in the catalyst serves both to improve catalytic activity and to inhibit sulfur pickup.
4. The loss of surface area is independent of the extent of sulfur pickup.
5. Platinum at the 0.1% level does not enhance catalytic activity.
6. Vanadium at the 2% level does not enhance catalytic activity, although it does inhibit sulfur pickup.
7. Lower feed gas space velocity does not improve catalytic activity.
8. Catalysts with a silica carrier show less shift at lower temperatures, in spite of higher steam.
9. Alumina carriers have not performed in this application.

FUTURE WORK

During the final two quarters of the contract period we will conduct a final extensive test of the two best catalysts including variations in temperature, steam, and feed gas composition. A test of these catalysts after reduction with clean hydrogen will also be conducted, to test their activity as unsulfided methanation catalysts.

If in further testing a low temperature catalyst is not developed a different process scheme may be required. The high temperature catalyst should still be tested for three months since it would still be applicable for a first stage high temperature reactor.

The life test will be conducted during the final quarter to finish the contract work.

TABLE II

SUMMARY OF CATALYST PREPARATIONS FOR ERDA
CONTRACT E(49-18)-2032

% Metals(s)	% Al ₂ O ₃	Crush	Density	% Na, New	% C, (a) Used	% S New	Surface Area		Pore Vol.		Crystallite		
		(lbs. DWL), New	(lbs. / CF), New				(m ² /g) New	Used	(cc/g) New	Used	Size (Å) New	Used	
71.4% NiO	28.6	15	49	0.038	2.61	.08	14.5	226	58.5	.592	.757	40	
76.7% Co ₂ O ₃	23.3	5	74	.018	1.99	.06	18.7	148	70.6	.479		65	
75.3% Fe ₂ O ₃	24.7	12	81	.17	2.35	.05	6.44	140	24.6	.360	.420	amor.	
74.6% CuO	25.4	17	62	.13		.03		104		.566		55	
69.0% MnO ₂	30.7	10	65	.25	3.03	.02	15.9	45.1	15.9	.505	.383	unid. (b)	
73.1% Cr ₂ O ₃	26.9	9	54	.045	2.21	.06	0.10	255	124	.645			
59.6% NiO) 13.4% Fe ₂ O ₃)	27.0	18	58	.08	2.29	.10	12.7	239	22.9	.732	.646	35 (NiO)	
54.9% NiO) 13.4% Cr ₂ O ₃	31.7	15	53	.02	3.04	.06	10.2 (5.9)	345	111	.666	.639	35 amor. (Ni ₃ S ₂)	225
55.9% NiO) 18.4% MnO ₂)	25.7	14	44	.2		.08		209		.830			
61.7% NiO) 11.0% CuO)	27.2	17	43	.02		.10		208		.684			
57.3% NiO) 13.9% Co ₂ O ₃)	28.7	17	49	.02	1.71	.13	14.7	188	29.4	.863	.456	unid.	
76% Fe ₂ O ₃) 20% K ₂ CO ₃) 4% Cr ₂ O ₃)	0.0	25	70	-		.15	13.0	6.1	2.6	.256	.202	200 (Fe ₂ O ₃)	225 (Fe ₃ O ₄)
74.5% Fe ₂ O ₃) 20% K ₂ CO ₃) 3.5% V ₂ O ₅) 2% Cr ₂ O ₃)	0.0	25	80	-	1.92	.32	1.21	2.1	3.8	.357	.126	200 (Fe ₂ O ₃)	225 (Fe ₃ O ₄)

(a) Two to three percent graphite added for tableting.

(b) Catalyst shows an unidentifiable XRD phase.

TABLE II

SUMMARY OF CATALYST PREPARATIONS FOR ERDA
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% Metal(s)	% Al ₂ O ₃	Crush	Density	% Na, New	% C, Used	% S		Surface Area (m ² /g)		Pore Vol. (cc/g)		Crystallite Size (Å)	
		(lbs. DWL), New	(lbs. / CF), New			New	Used	New	Used	New	Used	New	Used
3.5% CoO) 14 % MoO ₃)	82.5	15	36	.05	.23	.04	3.74	211	178	.888	.507	50 (γ -Al ₂ O ₃)	
3.5% NiO) 14 % MoO ₃)	82.5	15	48	.05	.13	.02	3.72	158	146	.615	.486	45 (γ -Al ₂ O ₃)	
25.7% CoO) 49.3% MoO ₃)	25.0	20	109	-	1.0	.01	.97	34.8	57.6	.157	.191		
25.7% NiO) 49.3% MoO ₃)	25.0	12	82	-	.54	.02	10.3	45.9	63.9	.212	.246		
51.2% Fe ₂ O ₃) 48.8% Cr ₂ O ₃)	-	12	97	-		.09		38.6	25.4	.238			
60.5% Fe ₂ O ₃) 14.5% Cr ₂ O ₃)	25.0	27	74	-		.06	.104	123	62.1	.316			
26.7% Fe ₂ O ₃) 48.3% MoO ₃) 2.3% Cr ₂ O ₃)	22.7	22	83	-		.04		64.5	40.0	.242			
18.4% NiO) 56.6% WO ₃)	25.0	14	85	-		.09		74.0		.303			
66.4% NiO) 33.6% Cr ₂ O ₃) (2/1)	-	4	88	-		.03	6.71	101.0	13.2	.240	.249		

TABLE II

SUMMARY OF CATALYST PREPARATIONS FOR ERDA
CONTRACT E(49-18)-2032

% Metal(s)	% Al ₂ O ₃	Crush	(lbs./CF) New	% Na, New	% C Used	% S		Surface Area (m ² /g)		Pore Vol. (cc/g)		Crystallite Size (Å)	
		(lbs.DWL), New				New	Used	New	Used	New	Used	New	Used
50.5% NiO) 49.5% Cr ₂ O ₃) (1/1)	-	2	68	-		.02	.15	65	5.7	.385	.456		
67.8% Fe ₂ O ₃) 32.2% Cr ₂ O ₃) (2/1)	-	5	83	-		.06	.15	124	29.1				
51% Fe ₂ O ₃) 49% Cr ₂ O ₃) (1/1)	-	5	82	-									
71.4% NiO) - % V ₂ O ₅)	28.6	15	49	.038		.10	8.65	193	14.4				
60.5% Fe ₂ O ₃) 14.5% Cr ₂ O ₃) - % V ₂ O ₅)	25.0	27	74	-		.06							
75.3% Fe ₂ O ₃) 1.76% V ₂ O ₅)	24.7	12	81	.17		.05	4.83	132	35.9	.227			
49.7% NiO) 25.3% Cr ₂ O ₃) 25.0% MgO)	-	6	77			.06	3.2	85.8	49.5	.252	.170		
49.7% NiO) 25.3% Cr ₂ O ₃) 25.0% SiO ₂)	-	9	47			.04	1.2	76.1	97.1	.368	.505		

SUMMARY OF CATALYST PREPARATIONS FOR ERDA
CONTRACT E(49-18)-2032

% Metal(s)	% Al ₂ O ₃	Crush (lbs. DWL), New	Density (lbs./CF) New	% Na, New	% C Used	% S New Used	Surface Area (m ² /g) New Used	Pore Vol. (cc/g) New Used	Crystallite Size Å New Used
48.7% Ni) 25.8% Cr) 2 % V) 24.5% MgAl ₂ O ₄)	-	3	44		1.76	.02 3.1	182 83.0		
% Ni) % V) % MgAl ₂ O ₄)	-	21	73		3.24	.02 11.7	151 31.9	.348	
60% Ni) 2% V) 38% SiO ₂)	-	20	55		2.58	.03 7.6	280 168		
% Ni) 0.1% Pt) % MgSiO ₃)	-	25	84		4.31	.01	201 97.9		
60 % Ni) 0.1% Pt) 40 % SiO ₂)	-	20	55						
73% NiO) 2% MnO ₂) 25% MgSiO ₃)	-	25	84		4.18	.01	73.7 42.6		
50.5% NiO) 49.5% Cr ₂ O ₃) .1% Pt)	-	2	68						

TABLE II

[illegible]

Table III
CATALYST TESTING SUMMARY

CATALYST TESTING SUMMARY																				
Run No.	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet S.V. v/v/hr.	S/G		% CO		%CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F		% of Bed above Hot Spot	% CO Conversion
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out
14	1Ni/1Cr	6	500	10,000	.424	.345	5.26	2.41	2.32	4.64	24.46	26.77	67.96	66.18	-	-	800	-	-	52.7
		12	500	10,000	.425	.363	4.89	2.38	2.37	4.49	-	-	-	-	-	-	-	-	-	-
		16	500	10,000	.380	.295	5.25	1.32	2.42	5.12	25.18	27.19	67.15	66.37	-	-	-	-	-	74.2
		21	500	10,000	.399	.246	4.33	1.31	3.45	5.95	24.64	26.86	67.58	65.88	-	-	-	-	-	68.8
		27	500	10,000	.422	.270	4.63	1.18	3.48	6.14	24.82	26.90	67.07	65.78	-	-	-	-	-	73.8
	(1050° Gas Comp)	(32)	500	10,000	.318	.222	9.30	4.33	4.12	7.48	38.14	40.48	48.44	47.71	-	-	1049	-	-	51.6
		(38)	500	10,000	.299	.237	9.42	4.66	4.20	7.33	38.12	39.93	48.26	48.08	-	-	-	-	-	49.0
		(41)	500	10,000	.299	.244	8.80	4.21	4.23	6.88	38.74	39.80	48.23	49.11	-	-	-	-	-	51.3
		(48)	500	10,000	.219	.177	10.09	6.81	3.93	5.32	47.94	46.99	38.04	40.88	3.0	100.4	1148	-	0.0	33.7
		(1150° Gas Comp)	(53)	500	10,000	.206	.182	9.84	6.71	4.31	5.44	48.08	49.92	37.77	37.93	2.7	23.2	1141	1152	23.7
(58)	500	10,000	.206	.185	9.91	5.82	4.53	6.30	48.53	48.06	37.03	39.82	-	-	-	-	-	41.8		
1Fe/1Cr		6	500	10,000	.434	.397	5.26	1.05	2.32	5.58	24.46	27.81	67.96	65.56	-	-	800	-	-	79.1
		12	500	10,000	.446	.380	4.89	.883	2.37	5.73	-	-	-	-	-	-	-	-	-	-
		16	500	10,000	.446	.402	5.25	.991	2.42	5.30	25.18	27.50	67.15	66.21	-	-	-	-	-	80.5
		21	500	10,000	.434	.324	4.33	1.10	3.45	6.13	24.64	26.78	67.58	65.99	-	-	-	-	-	73.9
		27	500	10,000	.432	.301	4.63	.960	3.48	6.23	24.82	27.06	67.07	65.75	-	-	-	-	-	78.6
	(1050° Gas Comp)	(32)	500	10,000	.319	.242	9.30	4.37	4.12	7.42	38.14	40.48	48.44	47.73	-	-	1050	-	-	51.2
		(38)	500	10,000	.315	.192	9.42	6.64	4.20	4.11	38.12	29.43	48.26	59.82	-	-	-	-	-	38.2
		(41)	500	10,000	.315	.296	8.80	3.09	4.23	7.33	38.74	40.78	48.23	48.80	-	-	-	-	-	63.7
		(48)	500	10,000	.227	.161	10.09	7.34	3.93	5.56	47.94	48.82	38.04	38.28	3.0	8.3	1143	-	28.6	26.0
		(1150° Gas Comp)	(53)	500	10,000	.220	.152	9.84	5.94	4.31	5.61	48.08	49.47	37.77	38.98	2.7	4.9	1145	1142	16.7
(58)	500	10,000	.211	.191	9.91	6.04	4.53	6.65	48.53	49.58	37.03	37.73	-	-	-	-	-	37.8		

Table III
CATALYST TESTING SUMMARY

Run No.	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet S.V. v/v/hr.	S/G		% CO		% CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F		% of Bed above Hot Spot	% CO Conversion
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
15	Ni-Cr-MgO	5	500	10,000	.276	.220	5.60	2.78	4.72	7.09	23.34	25.99	66.34	64.14	-	-	-	-	-	48.6
		9	500	10,000	.276	.231	5.79	1.44	4.79	7.68	23.53	26.29	65.89	64.59	-	-	-	-	-	74.2
		15	500	10,000	.276	.263	5.85	1.67	4.65	7.60	23.80	26.59	65.70	64.14	4.3	33.4	-	-	-	70.4
	(1150° Gas Comp)	18	500	10,000	.654	.537	10.06	3.91	4.54	7.85	48.00	49.34	37.40	38.90	-	-	1148	1161	48.8	60.1
		23	500	10,000	.339	.252	10.03	6.03	4.52	7.41	47.76	49.60	31.68	30.48	-	-	1095	1092	25.6	36.7
		28	500	10,000	.323	.179	3.53	2.18	3.60	5.66	26.46	28.88	65.17	61.50	-	-	807	809	48.8	35.6
		33	500	10,000	.326	.244	5.05	1.80	3.93	6.01	25.50	27.43	62.00	61.19	-	-	806	812	72.1	63.3
	Ni-Cr-MgSiO ₃	5	500	10,000	.346	.256	5.60	1.83	4.72	7.81	23.34	-	66.34	-	-	-	-	-	-	-
		9	500	10,000	.335	.295	5.79	2.42	4.79	7.01	23.53	25.35	65.89	65.22	-	-	-	-	-	57.2
		15	500	10,000	.337	.335	5.85	2.56	4.65	6.89	23.80	25.94	65.70	64.61	4.3	29.5	-	-	-	55.0
		18	500	10,000	.301	.445	10.06	5.03	4.54	6.15	48.00	42.97	37.40	45.85	-	-	1174	1226	71.0	54.4
		23	500	10,000	.318	.338	10.03	4.74	4.52	6.78	47.76	46.95	31.68	36.35	-	-	1104	1122	71.0	54.4
	(1150° Gas Comp)	28	500	10,000	.316	.332	3.53	2.75	3.60	4.38	26.46	27.42	65.17	61.42	-	-	807	806	18.4	17.8
		33	500	10,000	.318	.301	5.05	3.65	3.93	4.85	25.50	26.21	62.00	65.38	-	-	808	810	57.9	30.6

Table III
CATALYST TESTING SUMMARY

CATALYST TESTING SUMMARY																					
Run No.	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet	S/G	% CO		%CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F		% of Bed	% CO Conversion		
				S.V. v/v/hr.		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In		Out	Hot Spot above
16	Ni-Cr-	3	500	10,000	.284	.160	4.69	3.56	3.97	4.58	25.11	25.52	56.16	63.79	-	-	807	800	-	31.6	
	SiO ₂	7	500	10,000	.295	.198	5.38	4.08	3.72	4.42	25.42	25.61	64.68	74.06	-	-	-	-	-	32.2	
	(1150°	(14	500	10,000	-	.553	11.11	5.67	4.63	8.02	43.80	45.34	33.34	33.01	-	-	1104	1116	-	46.4	
	Gas Comp)	(18	500	10,000	-	.354	11.61	5.86	4.74	7.56	43.39	43.60	37.77	37.77	-	-	-	-	-	46.6	
	Ni-Cr-	3	500	10,000	.315	.258	4.69	1.27	3.97	6.32	25.11	27.08	56.16	62.60	-	-	815	814	-	75.0	
	MgAl ₂ O ₄	7	500	10,000	.311	.222	5.38	1.35	3.72	5.88	25.42	27.07	64.68	67.34	-	-	-	-	-	75.2	
	(1150°	(14	500	10,000	.307	.245	11.11	6.53	4.63	7.66	43.80	44.89	33.34	33.28	-	-	1112	1119	-	39.2	
	Gas Comp)	(18	500	10,000	.329	.197	11.61	6.47	4.74	7.51	43.39	44.11	37.77	36.93	-	-	-	-	-	40.8	
	17	Ni-Cr	5	500	10,000	.282	.188	5.12	2.17	3.36	5.65	24.18	25.69	67.34	66.49	-	-	811	805	45.0	56.8
		(1150°	(9	500	10,000	.307	.211	10.81	6.99	4.71	6.83	42.88	43.11	37.77	37.84	-	-	1122	1112	32.5	33.3
Gas Comp)		(12	500	10,000	.267	.239	10.23	5.20	4.44	6.59	50.74	52.44	38.19	30.91	-	-	1112	1108	45.0	37.1	
Ni-Cr-		5	500	10,000	.313	.284	5.12	2.06	3.36	5.59	24.18	25.74	67.34	66.49	-	-	813	808	32.5	58.9	
Al ₂ O ₃		(9	500	10,000	.341	.282	10.81	5.46	4.71	7.37	42.88	41.18	37.77	37.44	-	-	1131	1139	57.5	46.5	
(1150°		(12	500	10,000	.294	.217	10.23	4.98	4.44	5.89	50.74	48.88	38.19	38.30	-	-	1132	1137	57.5	47.7	
Gas Comp)																					
18		Pt-	4	500	10,000	.326	.334	4.87	1.34	3.45	4.92	24.57	25.80	64.17	62.87	-	-	-	-	-	71.1
		Al ₂ O ₃	(7	500	10,000	.318	.228	12.66	9.66	4.44	5.60	50.01	54.40	30.96	32.22	-	-	1113	1110	34.9	22.8
		Ru-	4	500	10,000	.335	.247	4.87	3.18	3.45	4.46	24.57	25.68	64.17	63.26	-	-	-	-	-	33.2
	Al ₂ O ₃	(7	500	10,000	.345	.479	12.66	7.31	4.44	6.97	50.01	55.87	30.96	31.77	-	-	1112	1100	56.1	39.7	

Table III
CATALYST TESTING SUMMARY

Run No.	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet S. V. v/v/hr.	S/G		% CO		% CO ₂		% H ₂		% CH ₄		Temperature, °F			% of Bed above Hot Spot	% CO Conversion
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Hot Spot	Out		
19	Ni/Cr/ MgAl ₂ O ₄	4	500	10,000	.458	.367	4.36	1.78	3.40	5.14	25.84	28.03	58.34	57.20	612	615	599	29.7	57.9
		8	500	10,000	.447	.348	3.95	.703	3.35	5.83	26.40	27.79	63.75	62.55	718	723	703	29.7	81.7
		13	500	10,000	.458	.356	3.89	.712	3.35	5.77	26.55	28.75	64.05	60.72	818	822	804	29.7	80.6
		17	500	10,000	.267	.168	8.86	4.88	4.37	6.94	48.27	48.89	32.01	29.24	918	920	897	29.7	39.3
		21	500	10,000	.217	.147	10.45	5.05	4.42	7.46	52.89	55.39	33.17	29.82	918	922	905	43.2	45.2
		25	500	10,000	.202	.111	8.00	4.43	4.18	6.05	52.70	53.73	34.29	32.04	915	916	895	16.2	39.5
		41	500	10,000	.207	.151	10.65	6.34	4.20	7.03	46.85	47.89	35.96	35.31	1025	1041	1007	29.7	37.9
		48	500	10,000	.187	.161	9.03	5.81	4.03	5.70	50.60	50.17	30.53	35.99	1035	1055	1011	56.8	41.0
		65	500	10,000	.199	.207	10.16	4.74	4.18	6.08	45.89	39.04	45.73	56.55	1187	1223	1136	29.7	58.4
		69	500	10,000	.199	.283	9.22	4.16	3.99	4.26	48.91	39.09	40.36	51.20	1180	1291	1130	29.7	59.5
		75	500	10,000	0	.0022	18.37	18.37	2.48	2.48	68.50	69.53	10.0	10.0	509	510	510	-	-
		80	500	10,000	0	-	-	-	-	-	No Reaction			-	665	666	661	-	-
		85	500	10,000	0	-	-	-	-	-	No Reaction			-	757	753	767	-	-
		92	500	10,000	0	.0039	17.56	19.12	2.05	1.94	-	-	30.55	30.39	926	937	914	29.7	-
	Ni/Cr/ MgSiO ₃	4	500	10,000	.447	.527	4.36	3.55	3.40	4.04	25.84	27.24	58.34	59.78	603	606	603	48.6	20.1
		8	500	10,000	.447	.457	3.95	2.26	3.35	4.69	26.40	27.02	63.75	66.91	711	714	709	48.6	45.0
		13	500	10,000	.443	.457	3.89	1.62	3.35	5.18	26.55	28.19	64.05	61.11	812	815	809	35.1	56.3
		17	500	10,000	.226	.118	8.86	7.08	4.37	3.93	48.27	43.10	32.01	41.36	955	1034	976	48.6	31.0
		21	500	10,000	.280	.267	10.45	5.02	4.42	7.20	52.89	55.06	33.17	30.30	913	920	903	35.1	45.7
		25	500	10,000	.198	.137	8.00	5.51	4.18	5.03	52.70	52.69	34.29	32.27	913	920	905	48.6	25.2
		41	500	10,000	.200	.147	10.65	7.33	4.20	3.99	46.85	34.90	35.96	49.65	1060	1159	1113	62.2	42.6
		48	500	10,000	.192	.097	9.03	4.64	4.03	3.07	50.60	36.59	30.53	53.97	1199	1248	1059	21.6	63.7
		65	500	10,000	.415	.210	10.16	6.02	4.18	6.48	45.89	40.57	45.73	78.66	1147	1201	1156	35.1	61.0
		69	500	10,000	.224	.305	9.22	3.48	3.99	4.30	48.91	38.64	40.36	48.71	1140	1260	1160	35.1	64.2
		75	500	10,000	0	.0024	18.37	18.37	2.48	2.48	68.51	69.52	10.0	10.0	511	512	512	-	-
		80	500	10,000	0	-	-	-	-	-	No Reaction			-	670	670	-	-	-
		85	500	10,000	0	-	-	-	-	-	No Reaction			-	757	756	-	-	-
		92	500	10,000	0	.0066	17.56	19.90	2.05	1.96	-	-	30.55	29.52	935	930	921	48.6	-

TABLE III
CATALYST TESTING SUMMARY

Run No.	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet S.V. v/v/hr.	S/G		%CO		%CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F		% Bed above Hot Spot	% CO Conv.	
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	Spot		
19 (cont'd)	Ni/Cr/ MgSiO ₃	5	500	10,000	.247	.133	9.22	6.12	3.45	4.11	39.78	34.58	41.84	55.13	-	-	1067	-	-	44.6	
		10	500	10,000	.232	.120	9.63	7.16	3.36	4.58	40.55	40.60	40.31	55.81	5.0	112.3	1013	1035	77.8	41.3	
		14	500	10,000	.075	.054	11.89	5.34	4.49	4.49	47.81	37.36	35.81	52.81	-	-	1249	1125	36.1	62.6	
		19	500	10,000	.081	.111	12.29	7.52	4.44	4.97	46.89	40.50	36.38	47.01	-	-	1044	1056	63.9	45.4	
		25	500	5,000	.074	.138	12.38	5.79	4.06	4.54	46.42	35.32	37.17	54.35	-	-	1152	-	36.1	61.2	
		30	500	5,000	.034	.131	12.11	5.36	4.63	4.85	47.11	35.18	36.15	54.61	-	-	1152	-	50.0	63.9	
	Ni/Cr/ MgAl ₂ O ₄	5	500	10,000	.173	.078	9.22	10.16	3.45	4.59	39.78	39.59	41.84	60.57	-	-	1012	-	-	20.3	
		10	500	10,000	.215	.074	9.63	6.80	3.36	5.15	40.55	42.66	40.31	41.12	5.0	122.6	1012	1016	57.5	29.1	
		14	500	10,000	.093	.021	11.89	6.99	4.49	4.30	47.81	41.75	35.81	46.96	-	-	1209	1142	32.5	47.3	
		19	500	10,000	.081	.065	12.29	11.09	4.44	4.30	46.89	45.84	36.38	36.38	-	-	1011	1118	57.5	11.5	
		25	500	5,000	.144	.094	12.38	8.28	4.06	4.31	46.42	38.68	37.17	48.73	-	-	1136	1115	45.0	41.5	
		30	500	5,000	.049	.079	12.11	7.25	4.63	4.81	47.11	37.77	36.15	50.17	-	-	1138	1124	57.5	49.1	
	20	Pt/MgSiO ₃	3	500	10,000	.426	.087	5.22	5.30	3.09	3.07	26.69	28.09	65.00	63.54	-	-	808	811	100.0	0.0
			13	500	10,000	.395	.615	5.12	2.88	3.46	4.98	25.07	27.42	66.35	64.72	5.5	9.8	810	819	77.5	41.9
18			500	10,000	.206	.070	12.01	12.05	4.69	4.08	47.70	49.57	35.60	34.30	-	-	1102	1107	52.5	0.0	
22			500	10,000	-	-	10.85	9.38	4.68	6.07	44.97	45.75	39.50	38.80	-	-	-	-	55.0	12.3	
Ru/MgSiO ₃		3	500	10,000	.375	.274	5.22	4.82	3.09	2.66	26.69	29.93	65.00	62.59	-	-	812	816	20.5	3.4	
		7	500	10,000	.375	.300	5.32	5.07	3.84	3.67	23.32	25.73	67.52	65.53	-	-	-	818	71.8	1.6	
		13	500	10,000	.375	.276	5.12	4.92	3.46	3.47	25.07	26.50	66.35	65.11	5.5	3.0	817	819	33.3	2.0	
		18	500	10,000	.190	.149	12.01	10.89	4.69	4.90	47.70	49.94	35.60	34.27	-	-	1109	-	59.0	5.3	
		22	500	10,000	-	-	10.85	11.03	4.68	4.96	44.97	48.93	39.50	35.08	-	-	-	-	-	0.0	

TABLE III
CATALYST TESTING SUMMARY

Run No.	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet S. V. v/v/hr.	S/G		%CO		%CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F.		% of Bed above Hot Spot	% CO Conv.
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
21	Ni/ MgAl ₂ O ₄	19	500	10,000	.419	.219	5.27	2.04	4.13	6.33	23.26	26.93	67.34	64.70	--	--	815	817	45.2	59.3
		25	500	10,000	.419	.213	5.30	2.07	4.18	6.22	25.35	27.77	65.17	63.94	--	--	--	--	--	59.6
		30	500	10,000	.252	.140	11.64	8.97	4.35	5.48	49.31	50.29	34.70	35.26	5.31	1025	--	--	--	21.4
		34	500	10,000	.252	.177	11.87	7.85	4.33	6.06	48.93	50.15	34.87	35.94	--	--	--	--	--	32.2
	Ni/ MgSiO ₃	19	500	10,000	.428	.422	5.27	3.81	4.13	5.10	23.26	24.73	67.34	66.36	--	--	812	812	29.4	26.3
		25	500	10,000	.428	.452	5.30	3.48	4.18	5.16	25.35	26.83	65.17	64.53	--	--	--	--	--	33.0
		30	500	10,000	.196	.234	11.64	7.27	4.35	6.69	49.31	51.77	34.70	34.27	5.3	713	--	--	--	34.5
		34	500	10,000	.196	.234	11.87	9.50	4.33	4.94	48.93	49.39	34.87	36.17	--	--	--	--	--	19.2
	Ni/Al ₂ O ₃	3	500	10,000	.385	.308	5.38	4.35	3.67	3.77	25.79	30.04	65.16	61.84	--	--	809	806	41.0	14.2
		7	500	10,000	.385	.282	5.51	5.19	3.49	3.68	27.55	28.74	63.45	62.39	--	--	--	--	--	4.2
		31	500	10,000	.183	.185	11.51	10.00	4.50	5.67	49.67	50.24	34.32	34.09	--	--	1110	1113	41.0	12.1
		36	500	10,000	.183	.185	11.59	9.24	4.48	5.92	48.38	50.35	35.55	34.49	7.1	57.6	1110	1105	35.0	17.1
	Ni/Cr/V/ MgSiO ₃	3	500	10,000	.416	.388	5.38	1.25	3.67	6.29	25.79	32.36	65.16	60.10	--	--	821	814	10.0	74.5
		7	500	10,000	.416	.403	5.51	1.25	3.49	6.19	27.55	31.79	63.45	60.77	--	--	--	--	--	75.9
		31	500	10,000	.180	.265	11.51	5.89	4.50	6.49	49.67	44.23	34.32	43.39	--	--	1184	1142	47.5	53.8
		36	500	10,000	.188	.257	11.59	6.16	4.48	6.66	48.38	46.24	35.55	40.94	7.1	77.3	1187	1133	15.4	49.0
22	Ni/Al ₂ O ₃	3	500	10,000	.385	.308	5.38	4.35	3.67	3.77	25.79	30.04	65.16	61.84	--	--	809	806	41.0	14.2
		7	500	10,000	.385	.282	5.51	5.19	3.49	3.68	27.55	28.74	63.45	62.39	--	--	--	--	--	4.2
		31	500	10,000	.183	.185	11.51	10.00	4.50	5.67	49.67	50.24	34.32	34.09	--	--	1110	1113	41.0	12.1
		36	500	10,000	.183	.185	11.59	9.24	4.48	5.92	48.38	50.35	35.55	34.49	7.1	57.6	1110	1105	35.0	17.1

TABLE III
CATALYST TESTING SUMMARY

No. Run	Metal	Time On Stream Hrs.	Pressure PSIG	Dry Inlet S.V. v/v/hr.	S/G		% CO		% CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F		% of Bed above Hot Spot	% CO Conversion
					In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out		
23	Ni/V/ MgSiO ₃	3	500	10,000	-	.216	5.18	3.50	3.64	4.76	26.66	28.95	64.52	62.79	-	-	824	833	78.4	30.3
		9	500	10,000	.438	.275	5.14	2.97	3.58	5.22	27.27	29.03	64.01	62.78	-	-	835	852	100	40.8
		13	500	10,000	.224	.276	11.39	6.98	4.41	6.52	49.38	53.00	34.82	33.50	-	-	1125	1131	100	34.0
		18	500	10,000	.208	.294	11.31	7.48	4.46	7.03	49.23	50.72	35.00	34.77	-	-	1121	1131	100	31.9
	Ni/Cr/V MgAl ₂ O ₄	3	500	10,000	-	.249	5.18	1.14	3.64	6.31	26.66	30.57	64.52	61.98	-	-	841	839	32.4	76.8
		9	500	10,000	.391	.328	5.14	0.43	3.58	6.77	27.27	30.77	64.01	62.03	-	-	847	856	100	91.2
		13	500	10,000	.236	.238	11.39	5.95	4.41	6.56	49.38	48.79	34.82	38.70	-	-	1184	1151	17.6	48.4
		18	500	10,000	.225	.241	11.31	6.38	4.46	6.63	49.23	46.95	35.00	40.04	-	-	1206	1145	2.9	46.0

TABLE III
ATALYST TESTING SUMMARY

Run No.	Metal	Time On		Inlet S. V. v/v/hr.	S/G		% CO		% CO ₂		% H ₂		% CH ₄		ppm S		Temp., °F		% of Bed above Hot Spot	% CO Conversion	
		Stream Hrs.	Pressure PSIG		In	Out	In	Out	In	Out	In	Out	In	Out	In	Out	In	Out			
24	Ni/V/ SiO ₂	5	500	10,000	.415	.332	4.92	4.60	3.54	3.80	22.74	23.40	68.80	68.20	-	-	811	817	75.0	5.7	
		8	500	10,000	.216	.107	10.81	7.11	4.47	5.85	49.90	50.68	34.82	36.35	-	-	1163	1115	19.4	33.2	
		11	500	10,000	.217	.228	11.18	7.33	4.62	6.14	49.43	52.41	34.77	34.12	-	-	-	-	-	30.3	
	Ni/V/ MgAl ₂ O ₄	5	500	10,000	.423	.276	4.92	1.87	3.54	5.74	22.74	25.56	68.80	66.83	-	-	820	823	31.0	60.6	
		8	500	10,000	.196	.152	10.81	6.79	4.47	5.43	49.90	49.08	34.82	38.70	-	-	1182	1111	19.0	38.2	
		11		10,000	.183	.138	11.18	6.73	4.62	5.21	49.43	45.95	34.77	42.11	-	-	-	-	-	43.7	
	25	Ni/Mn/ MgSiO ₃	3	500	10,000	.381	-	4.69	1.72	3.58	5.51	26.87	33.81	64.86	58.96	-	-	810	805	21.1	59.5
			8	500	10,000	.215	.137	10.98	13.18	4.64	2.77	49.41	47.13	34.97	36.92	-	-	1099	1099	34.2	0
		Ni/Pt/ MgSiO ₃	3	500	10,000	.382	-	4.69	2.40	3.58	4.79	26.87	31.42	64.86	61.39	-	-	808	808	39.0	45.4
8			500	10,000	.221	.182	10.98	9.38	4.64	5.70	49.41	50.30	34.97	34.62	-	-	1107	1100	2.4	13.0	
26	1-1 Ni-Cr /Pt	7	500	10,000	.378	-	5.07	2.83	3.58	5.32	26.35	27.97	65.00	63.88	15.1	51.4	816	818	82.5	42.9	
		11	500	10,000	.167	.202	11.17	7.99	5.01	7.03	48.07	50.03	35.75	34.95	-	-	1116	1118	68.6	25.7	
	Ni/Pt/SiO ₂	7	500	10,000	.353	-	5.07	4.86	3.58	3.79	26.35	26.99	65.00	64.36	15.1	62.5	810	802	32.4	3.3	
		11	500	10,000	.207	.184	11.17	10.03	5.01	5.46	48.07	49.27	35.75	35.24	-	-	-	-	-	8.1	

TABLE IV
CARBON MONOXIDE CHANGES

Run	Catalyst	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow (a)	Δ (b)	Δ (c)	% (d)	% (e)	% (f)
		In	Out	In	Out	In	Out	In	Out	Outlet, l/hr.	Moles CO ₂	Moles CH ₄	CO Shift	CO to CH ₄	CO Unreacted
14	1Ni/1Cr (900°)	24.46	26.77	5.26	2.41	2.32	4.64	67.97	66.18	103.15	2.47	.308	46.9	5.8	47.3
		25.18	27.19	5.25	1.32	2.42	5.12	67.15	66.37	102.76	2.84	1.05	54.1	20.0	25.8
		24.64	26.86	4.33	1.31	3.45	5.95	67.58	65.88	103.04	2.68	.300	61.9	6.9	31.2
		24.82	26.90	4.63	1.18	3.48	6.14	67.07	65.78	102.85	2.83	.582	61.2	12.6	26.2
	(1050° Gas Comp)	(38.14	40.48	9.30	4.33	4.12	7.48	48.44	47.71	103.93	3.65	1.146	39.3	12.3	48.4
		(38.12	39.93	9.42	4.66	4.20	7.33	48.26	48.08	103.01	3.35	1.269	35.6	13.5	51.0
		(38.74	39.80	8.80	4.21	4.23	6.88	48.23	49.11	101.76	2.77	1.745	31.5	19.8	48.7
		(47.94	46.99	10.09	6.81	3.93	5.32	38.04	40.88	98.21	1.29	2.11	12.8	20.9	66.3
	(1150° Gas Comp)	(48.08	49.92	9.84	6.71	4.31	5.44	37.77	37.93	103.67	1.33	1.55	13.5	15.8	70.7
		(48.53	48.06	9.91	5.82	4.53	6.30	37.03	39.82	99.10	1.71	2.43	17.3	24.5	58.2
	2Fe/1Cr (900°)	24.46	27.81	5.26	1.05	2.32	5.58	67.96	65.56	104.64	3.52	.642	66.9	12.2	20.9
		25.18	27.50	5.25	.991	2.42	5.30	67.15	66.21	103.20	3.05	1.09	58.1	20.7	19.5
		24.64	26.78	4.33	1.10	3.45	6.13	67.58	65.99	102.92	2.86	.339	66.0	7.8	26.1
		24.82	27.06	4.63	.960	3.48	6.23	67.07	65.75	103.07	2.94	.699	63.5	15.1	21.4
	(1050° Gas Comp)	(38.14	40.48	9.30	4.37	4.12	7.42	48.44	47.73	103.93	3.59	1.166	38.6	12.5	48.8
		(38.12	29.43	9.42	6.64	4.20	4.11	48.26	59.82	87.69	-.596	4.19	-6.3	44.5	61.8
		(38.74	40.78	8.80	3.09	4.23	7.33	48.23	48.80	103.44	3.35	2.25	38.1	25.6	36.3
		(47.94	48.82	10.09	7.34	3.93	5.56	38.04	38.28	101.72	1.73	.898	17.1	8.9	74.0
	(1150° Gas Comp)	(48.08	49.47	9.84	5.94	4.31	5.61	37.77	38.98	102.75	1.45	2.28	14.8	23.2	62.0
		(48.53	49.58	9.91	6.04	4.53	6.65	37.03	37.73	102.08	2.26	1.49	22.8	15.0	62.2

(a.) Outlet flow = inlet flow x carbon factor, where inlet flow = 100 l/hr. (assumed); carbon factor = $\frac{\text{carbon in}}{\text{carbon out}} = \frac{100 - \% \text{ H}_2 \text{ in}}{100 - \% \text{ H}_2 \text{ out}}$

(b.) Δ moles CO₂ = mole % CO₂ out x outlet flow - mole % CO₂ in x inlet flow

(c.) Δ moles CH₄ = mole % CH₄ out x outlet flow - mole % CH₄ in x inlet flow

(d.) % CO shift = $\frac{\Delta \text{ moles CO}_2}{\text{mole \% CO in}} \times 100$

(e.) % CO to CH₄ = $\frac{\Delta \text{ moles CH}_4}{\text{mole \% CO in}} \times 100$

(f.) % CO unreacted = $\frac{\text{mole \% CO out} \times \text{outlet flow}}{\text{mole \% CO in} \times \text{inlet flow}} \times 100$

TABLE IV
CARBON MONOXIDE CHANGES

Run	Catalyst	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	Δ Moles CO ₂	Δ Moles CH ₄	% CO Shift	% CO to CH ₄	% CO Unreacted
		In	Out	In	Out	In	Out	In	Out						
15	1Ni/1Cr on MgO (1150° Gas Comp)	23.34	25.99	5.60	2.78	4.72	7.09	66.34	64.14	103.58	2.62	.097	46.9	1.7	51.4
		23.53	26.29	5.79	1.44	4.79	7.68	65.89	64.59	103.74	3.18	1.12	56.7	19.3	25.8
		23.80	26.59	5.85	1.67	4.65	7.60	65.70	64.14	103.80	3.24	.878	55.4	15.0	29.6
		48.00	49.34	10.06	3.91	4.54	7.85	37.40	38.90	102.65	3.52	2.53	35.0	25.1	39.9
		47.76	49.60	10.03	6.03	4.52	7.41	31.68	30.48	105.26	3.28	.403	32.7	4.0	63.3
		26.46	28.88	3.53	2.18	3.60	5.66	65.17	61.50	104.27	2.30	-1.04	65.2	-29.6	64.4
		25.50	27.43	5.05	1.80	3.93	6.01	62.00	61.19	102.87	2.25	.946	44.6	18.7	36.7
	1Ni/1Cr on MgSiO ₃ (1150° Gas Comp)	23.53	25.35	5.79	2.42	4.79	7.01	65.89	65.22	102.44	2.39	.920	41.3	15.9	42.8
		23.80	25.94	5.85	2.56	4.65	6.89	65.70	64.61	102.44	2.41	.485	41.3	8.3	44.8
		48.00	42.97	10.06	5.03	4.54	6.15	37.40	45.85	91.18	1.07	4.41	10.6	43.8	45.6
		47.76	46.95	10.03	4.74	4.52	6.78	31.68	31.35	96.57	2.03	3.42	20.2	34.1	45.6
		26.46	27.42	3.53	2.75	3.60	4.38	65.17	61.42	105.47	1.02	-.390	28.9	-11.0	82.2
		25.50	26.21	5.05	3.65	3.93	4.85	62.00	65.38	96.07	.720	.814	14.4	16.1	69.4

TABLE IV
CARBON MONOXIDE CHANGES

Run	Catalyst	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	Moles CO ₂	Moles CH ₄	% CO Shift	% CO to CH ₄	% CO Unreacted
		In	Out	In	Out	In	Out	In	Out						
16	Ni/Cr/SiO ₂ (1150° gas comp.)	25.11	25.52	4.69	3.56	3.97	4.58	56.16	63.79	90.12	.157	1.32	3.4	28.2	68.4
		25.42	25.61	5.38	4.08	3.72	4.42	64.68	74.06	89.37	.230	1.50	4.3	28.0	67.8
		(43.80	45.34	11.11	5.67	4.63	8.02	33.34	33.01	105.10	3.80	1.35	34.2	12.2	53.6
		(43.39	43.60	11.61	5.86	4.74	7.56	37.77	37.77	105.72	3.25	2.16	28.0	18.6	53.4
	Ni/Cr/MgAl ₂ O ₄ (1150° gas comp.)	25.11	27.08	4.69	1.27	3.97	6.32	56.16	62.60	92.30	1.87	1.65	39.8	35.2	25.0
		25.42	27.07	5.38	1.35	3.72	5.88	64.68	67.34	98.94	2.10	1.95	39.0	36.2	24.8
		(43.80	44.89	11.11	6.53	4.63	7.66	33.34	33.28	103.39	3.29	1.07	29.6	9.6	60.8
		(43.39	44.11	11.61	6.47	4.74	7.51	37.77	36.93	106.31	3.24	1.49	27.9	12.8	59.2
17	Ni/Cr (1150° gas comp.)	24.18	25.69	5.12	2.17	3.36	5.65	67.34	66.49	102.03	2.40	.501	47.0	9.8	43.2
		(42.88	43.11	10.81	6.99	4.71	6.83	37.77	37.84	103.16	2.34	1.26	21.6	11.7	66.7
		(50.74	52.44	10.23	5.20	4.44	6.59	38.19	30.91	123.79	3.72	.075	36.4	.73	62.9
	Ni/Cr/Al ₂ O ₃ (1150° gas comp.)	24.18	25.74	5.12	2.06	3.36	5.59	67.34	66.61	102.10	2.35	.669	45.8	13.1	41.1
		(42.88	41.18	10.81	5.46	4.71	7.37	37.77	37.44	106.01	3.10	1.92	28.7	17.8	53.5
		(50.74	48.88	10.23	4.98	4.44	5.89	38.19	38.30	107.50	1.89	2.98	18.5	29.2	52.3
18	Pt/Al ₂ O ₃	24.57	25.80	4.87	1.34	3.45	4.92	64.17	62.87	104.86	1.71	1.76	35.1	36.1	28.9
		(50.01	54.40	12.66	9.66	4.44	5.60	30.96	32.22	101.22	1.23	1.65	9.7	13.1	77.2
	Ru/Al ₂ O ₃	24.57	25.68	4.87	3.18	3.45	4.46	64.17	63.26	102.24	1.11	.509	22.8	10.4	66.8
		(50.01	55.87	12.66	7.31	4.44	6.97	30.96	31.77	104.36	2.83	2.20	22.4	17.4	57.7

TABLE IV
CARBON MONOXIDE CHANGES

Run	Catalyst	Temp °F	Mole % H ₂ In	Mole % H ₂ Out	Mole % CO In	Mole % CO Out	Mole % CO ₂ In	Mole % CO ₂ Out	Mole % CH ₄ In	Mole % CH ₄ Out	Flow Outlet, l/hr.	Δ Moles CO ₂	Δ Moles CH ₄	% CO Shift	% CO to CH ₄	% CO Unreacted	
19	Ni/Cr/ Mg/Al ₂ O ₄	600	25.84	28.03	4.36	1.78	3.40	5.14	58.34	57.20	103.09	1.90	.626	43.5	14.4	42.1	
		700	26.40	27.79	3.95	.703	3.35	5.83	63.75	62.55	102.85	2.65	.581	67.0	14.7	18.3	
		800	26.55	28.75	3.89	.712	3.35	5.77	64.05	60.72	106.08	2.77	.364	71.2	9.3	19.4	
		900	48.27	48.89	8.86	4.88	4.37	6.94	32.01	29.24	110.18	3.28	.207	37.0	2.3	60.7	
		900	52.89	55.39	10.45	5.05	4.42	7.46	33.17	29.82	113.49	4.05	.672	38.7	6.4	54.8	
		900	52.70	53.73	8.00	4.43	4.18	6.05	34.29	32.04	109.29	2.43	.726	30.4	9.1	60.5	
		1000	46.85	47.89	10.65	6.34	4.20	7.03	35.96	35.31	104.38	3.14	.895	29.5	8.4	62.1	
		1000	50.60	50.17	9.03	5.81	4.03	5.70	30.53	35.99	91.77	1.20	2.50	13.2	27.7	59.0	
		1100	45.89	39.04	10.16	4.74	4.18	6.08	45.73	56.55	89.16	1.24	4.69	12.2	46.2	41.6	
		1100	48.91	39.09	9.22	4.16	3.99	4.26	40.36	51.20	89.85	-.162	5.64	-1.8	61.2	40.5	
		500	68.50	69.53	18.37	18.37	2.48	2.48	10.0	10.0	No Reaction						
		670	No Reaction														
		750	No Reaction														
		910	-	-	17.56	19.12	2.05	1.94	30.55	30.39							
	Ni/Cr/ MgSiO ₃	600	25.84	27.24	4.36	3.55	3.40	4.04	58.34	59.78	98.11	.564	.313	12.9	7.2	80.0	
		700	26.40	27.02	3.95	2.26	3.35	4.69	63.75	66.91	96.20	1.16	.614	29.4	15.6	55.0	
		800	26.55	28.19	3.89	1.62	3.35	5.18	64.05	61.11	104.98	2.09	.102	53.7	2.6	43.7	
		900	48.27	43.10	8.86	7.08	4.37	3.93	32.01	41.36	86.39	-.975	3.72	-11.0	42.0	69.0	
		900	52.89	55.06	10.45	5.02	4.42	7.20	33.17	30.30	112.98	3.71	1.06	35.5	10.2	54.3	
		900	52.70	52.69	8.00	5.51	4.18	5.03	34.29	32.27	108.55	1.28	.739	16.0	9.2	74.8	
		1000	46.85	34.90	10.65	7.33	4.20	3.99	35.96	49.65	83.34	-.875	5.42	-8.2	50.9	57.4	
		1000	50.60	36.59	9.03	4.64	4.03	3.07	30.53	53.97	70.67	-1.86	7.61	-20.6	84.3	36.3	
		1100	45.89	40.57	10.16	6.02	4.18	6.48	45.73	78.66	65.90	.090	6.10	0.89	60.1	39.0	
		1100	48.91	38.64	9.22	3.48	3.99	4.30	40.36	48.71	94.83	.088	5.83	0.95	63.3	35.8	
		500	68.50	69.52	18.37	18.37	2.48	2.48	10.0	10.0	No Reaction						
		670	No Reaction														
		750	No Reaction														
		910	-	-	17.56	19.90	2.05	1.96	30.55	29.52							

TABLE IV
CARBON MONOXIDE CHANGES AT 800-1100° F

Run	Catalyst	Temp., °F	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	△	△	%	%	CO Unreacted	
			In	Out	In	Out	In	Out	In	Out		Moles CO ₂	Moles CH ₄	CO Shift	CO to CH ₄		
19 (cont'd)	Ni/Cr/MgSiO ₃	1000	39.78	34.58	9.22	6.12	3.45	4.11	41.84	55.13	83.4	-.0223	4.14	-.24	44.9	55.4	
		1000	40.55	40.60	9.63	7.16	3.36	4.58	40.31	55.81	78.9	.254	3.73	2.6	38.7	58.7	
		1100	47.81	37.36	11.89	5.34	4.49	4.49	35.81	52.81	83.3	-.749	8.19	-6.3	68.9	37.4	
		1000	46.89	40.50	12.29	7.52	4.44	4.97	36.38	47.01	89.3	.004	5.58	-.03	45.4	54.6	
		(5000 SV)	1100	46.42	35.32	12.38	5.79	4.06	4.54	37.17	54.35	41.4	-.297	7.88	-2.4	63.6	38.8
		(5000 SV)	1100	47.11	35.18	12.11	5.36	4.63	4.85	36.15	54.61	40.8	-.672	8.41	-5.6	69.4	36.1
19 (cont'd)	Ni/Cr/ MgAl ₂ O ₄	1000	39.78	39.59	9.22	10.16	3.45	4.59	41.84	60.57	72.4	-.128	2.00	-1.39	21.6	79.7	
		1000	40.55	42.66	9.63	6.80	3.36	5.15	40.31	41.12	100.4	1.81	0.99	19.9	10.3	70.9	
		1100	47.81	41.75	11.89	6.99	4.49	4.30	35.81	46.96	89.6	0.64	6.26	-5.4	52.7	52.7	
		1000	46.89	45.84	12.29	11.09	4.44	4.30	36.38	38.77	98.1	-.22	1.64	-1.8	13.3	88.5	
		(5000 SV)	1100	46.42	38.68	12.38	8.28	4.06	4.31	37.17	48.73	43.7	-.29	5.43	-2.4	43.9	58.5
		(5000 SV)	1100	47.11	37.77	12.11	7.25	4.63	4.81	36.15	50.17	42.5	-.54	6.49	-4.5	53.6	50.9

TABLE IV
CARBON MONOXIDE CHANGES AT 800-1100°F

Run	Catalyst	Temp., °F	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	Δ	Δ	%	%	CO Unreacted
			In	Out	In	Out	In	Out	In	Out		Moles CO ₂	Moles CH ₄	CO Shift	CO to CH ₄	
20	Pt/MgSiO ₃	800	26.69	28.09	5.22	5.30	3.09	3.07	65.00	63.54	101.9	.04	-.22	.76	-4.3	103.5
		800	25.07	27.42	5.12	2.88	3.46	4.98	66.35	64.72	103.2	1.7	.47	32.8	9.1	58.1
		1100	47.70	49.57	12.01	12.05	4.69	4.08	35.60	34.30	103.7	-.46	-.28	-3.8	-.23	104.1
		1100	44.97	45.75	10.85	9.38	4.68	6.07	39.50	38.80	101.4	1.5	-.14	13.6	-1.3	87.7
	Ru/MgSiO ₃	800	26.69	29.93	5.22	4.82	3.09	2.66	65.00	62.59	104.6	-.31	.48	-5.9	9.3	96.6
		800	23.32	25.73	5.32	5.07	3.84	3.67	67.52	65.53	103.2	-.05	.14	-.96	2.5	98.4
		800	25.07	26.50	5.12	4.92	3.46	3.47	66.35	65.11	101.7	.07	-.11	1.4	-2.1	100.7
		1100	47.70	49.94	12.01	10.89	4.69	4.90	35.60	34.27	104.4	.43	.20	3.6	1.7	94.7
		1100	44.97	48.93	10.85	11.03	4.68	4.96	39.50	35.08	107.8	.66	-1.7	6.1	-15.7	109.5

TABLE IV
CARBON MONOXIDE CHANGES AT 800-1100° F

Run	Catalyst	Temp., °F	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	Δ Moles CO ₂	Δ Moles CH ₄	% CO Shift	% CO to CH ₄	CO Unreacted
			In	Out	In	Out	In	Out	In	Out						
21	Ni/MgAl ₂ O ₄	800	23.26	26.93	5.27	2.04	4.13	6.33	67.34	64.70	105.0	2.5	.61	47.7	11.6	40.7
		800	25.35	27.77	5.30	2.07	4.18	6.22	65.17	63.94	103.4	2.2	.91	42.4	17.2	40.4
		1100	49.31	50.29	11.64	8.97	4.35	5.48	34.70	35.26	102.0	1.2	1.3	10.6	10.8	78.6
		1100	48.93	50.15	11.87	7.85	4.33	6.06	34.87	35.94	102.4	1.9	1.9	15.8	16.4	67.8
	Ni/MgSiO ₃	800	23.26	24.73	5.27	3.81	4.13	5.10	67.34	66.36	102.0	1.1	.32	20.3	6.0	73.7
		800	25.35	26.83	5.30	3.48	4.18	5.16	65.17	64.53	102.0	1.1	.67	20.5	12.6	67.0
		1100	49.31	51.77	11.64	7.27	4.35	6.69	34.70	34.27	105.1	2.7	1.3	23.0	11.3	65.6
		1100	48.93	49.39	11.87	9.50	4.33	4.94	34.87	36.17	100.9	.65	1.6	5.5	13.7	80.8
22	Ni/Al ₂ O ₃	800	25.79	30.04	5.38	4.35	3.67	3.77	65.16	61.84	106.1	.33	.44	6.1	8.1	85.8
		800	27.55	28.74	5.51	5.19	3.49	3.68	63.45	62.39	101.7	.25	-.02	4.6	-.33	95.8
		1100	49.67	50.24	11.51	10.0	4.50	5.67	34.32	34.09	101.1	1.2	.16	10.7	1.4	87.9
		1100	48.38	50.35	11.59	9.24	4.48	5.92	35.55	34.49	104.0	1.7	.31	14.5	2.7	82.9
	Ni/Cr/V/ MgSiO ₃	800	25.79	32.36	5.38	1.25	3.67	6.29	65.16	60.10	109.7	3.2	.78	60.1	14.5	25.5
		800	27.55	31.79	5.51	1.25	3.49	6.19	63.45	60.77	106.2	3.1	1.1	56.0	19.9	24.1
		1100	49.67	44.23	11.51	5.89	4.50	6.49	34.32	43.39	90.2	1.4	4.8	11.8	42.0	46.2
		1100	48.38	48.38	11.59	6.16	4.48	6.66	35.55	40.94	96.0	1.9	3.8	16.5	32.4	51.0

TABLE IV
CARBON MONOXIDE CHANGES AT 800-1100°F

Run	Catalyst	Temp., °F	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	Δ Moles CO ₂	Δ Moles CH ₄	% CO Shift	% CO to CH ₄	CO Unreacted
			In	Out	In	Out	In	Out	In	Out						
23	Ni/V/ MgSiO ₃	800	26.66	28.95	5.18	3.50	3.64	4.76	64.52	62.79	103.2	1.3	.29	24.6	5.7	69.7
		800	27.27	29.03	5.14	2.97	3.58	5.22	64.01	62.78	102.5	1.8	.33	34.4	6.4	59.2
		1100	49.38	53.00	11.39	6.98	4.41	6.52	34.82	33.50	107.7	2.6	1.3	22.9	11.1	66.0
		1100	49.23	50.72	11.31	7.48	4.46	7.03	35.00	34.77	103.0	2.8	.82	24.6	7.3	68.1
	Ni/Cr/V MgAl ₂ O ₄	800	26.66	30.57	5.18	1.14	3.64	6.31	64.52	61.98	105.6	3.0	.95	58.4	18.3	23.2
		800	27.27	30.77	5.14	0.43	3.58	6.77	64.01	62.03	105.1	3.5	1.2	68.7	22.5	8.8
		1100	49.38	48.79	11.39	5.95	4.41	6.56	34.82	38.70	98.8	2.1	3.4	18.2	30.1	51.6
		1100	49.23	46.95	11.31	6.38	4.46	6.63	35.00	40.04	95.7	1.9	3.3	16.7	29.3	54.0

TABLE IV
CARBON MONOXIDE CHANGES AT 800-1100°F

No. Run	Catalyst	Temp. °F	Mole % H ₂		Mole % CO		Mole % CO ₂		Mole % CH ₄		Flow Outlet, l/hr.	Moles CO ₂	Moles CH ₄	% CO Shift	% CO to CO CH ₄ Unreacted	
			In	Out	In	Out	In	Out	In	Out						
24	M/V/SiO ₂	800	22.74	23.40	4.92	4.60	3.54	3.80	58.80	68.20	100.9	.29	-.01	6.0	-.25	94.3
		1100	49.90	50.68	10.81	7.11	4.47	5.85	34.82	36.36	101.6	1.5	2.1	13.6	19.5	66.8
		1100	49.43	52.41	11.18	7.33	4.62	6.14	34.77	34.12	106.3	1.9	1.5	17.0	13.3	69.7
	Ni/V/ MgAl ₂ O ₄	800	22.74	25.56	4.92	1.87	3.54	5.74	68.80	66.83	103.8	2.4	.56	49.1	11.4	39.4
		1100	49.90	49.08	10.81	6.79	4.47	5.43	34.82	38.70	98.4	.87	3.3	8.1	30.1	61.8
		1100	49.43	45.95	11.18	6.73	4.62	5.21	34.77	42.11	93.6	.25	4.6	2.3	41.4	56.3
	Ni/Mn/ MgSiO ₃	800	26.87	33.81	4.69	1.72	3.58	5.51	64.86	58.96	110.5	2.5	.28	53.5	6.0	40.5
		1100	49.41	47.13	10.98	13.18	4.64	2.77	34.97	36.92	95.7	-2.0	.36	-18.1	3.3	114.9
	Ni/Pt/ MgSiO ₃	800	26.87	31.42	4.69	2.40	3.58	4.79	64.86	61.39	106.6	1.5	.60	32.6	12.9	54.6
		1100	49.41	50.30	10.98	9.38	4.64	5.70	34.97	34.62	101.8	1.2	.27	10.6	2.5	87.0
26	1-1 Ni-Cr/ Pt	800	26.35	27.97	5.07	2.83	3.58	5.32	65.00	63.88	102.2	1.9	.32	36.7	6.2	57.1
		1100	48.07	50.03	11.17	7.99	5.01	7.03	35.75	34.95	103.9	2.3	.57	20.6	5.1	74.3
	Ni/Pt/ SiO ₂	800	26.35	26.99	5.07	4.86	3.58	3.79	65.00	64.36	100.9	.24	-.08	4.8	-1.5	96.7
		1100	48.07	49.27	11.17	10.03	5.01	5.46	35.75	35.24	102.4	.58	.32	5.2	2.9	91.9
		800	26.35	26.99	5.07	4.86	3.58	3.79	65.00	64.36	100.9	.24	-.08	4.8	-1.5	96.7
		1100	48.07	49.27	11.17	10.03	5.01	5.46	35.75	35.24	102.4	.58	.32	5.2	2.9	91.9