TECHNOLOGY DEVELOPMENT FOR IRON FISCHER-TROPSCH CATALYSTS

CONTRACT DE-AC22-90PC90055

Technical Progress Report No. 7
4/1/92 - 6/30/92

prepared for

Pittsburgh Energy Technology Center
Department of Energy
Pittsburgh, Pennsylvania

prepared by

UOP
25 E. Algonquin Road
Des Plaines, Illinois

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TECHNOLOGY DEVELOPMENT FOR IRON FISCHER-TROPSCH CATALYSTS

Contract DE-AC22-90PC90055

**Technical Progress Report No. 7
4/1/92 - 7/31/92**

**by
Robert R. Frame and Hemant B. Gala**

**UOP
25 E. Algonquin Road
Des Plaines, Illinois**

CONTRACT OBJECTIVE

The objectives of this contract are to develop a technology for the production of active and stable iron Fischer-Tropsch catalysts for use in slurry-phase synthesis reactors and to develop a scaleup procedure for large-scale synthesis of such catalysts for process development and long-term testing in slurry bubble-column reactors. With a feed containing H_2 and CO in the molar ratio of 0.5 to 1.0 to the slurry bubble-column reactor, the catalyst performance target is 88% CO+ H_2 conversion at a minimum space velocity of 2.4 NL/hr/gFe. The desired sum of methane and ethane selectivities is no more than 4%, and the conversion loss per week is not to exceed 1%.

CONTRACT TASKS

- Task 1.0: Catalyst development
 - 1.1: Technology assessment
 - 1.2: Precipitated catalyst preparation method development
 - 1.3: Novel catalyst preparation methods investigation
 - 1.4: Catalyst pretreatment
 - 1.5: Catalyst characterization
- Task 2.0: Catalyst testing
- Task 3.0: Catalyst aging studies
- Task 4.0: Preliminary design and cost estimate of a catalyst synthesis facility

Scope of Work Reported

The work reported in this technical progress report covers three runs carried out with three different United Catalyst Inc. (UCI) catalysts. The UCI catalysts composition is reported in

Table 1, along with the previously tested UCI catalysts.

The objective of testing UCI catalysts in the slurry autoclave reactor at UOP was to provide support for the trial F-T run that was carried out in a slurry bubble-column reactor (SBCR) at the LaPorte Alternative Fuels Development Unit. Part of the work reported in this report was carried out with UOP funding. The data collected with UCI catalyst are quite important for the DOE contract because these data provide a direct one-to-one correlation between the autoclave and the bubble column tests.

For the tests carried out with the UCI "B" (Run 51) and UCI "Start-up" (Run 53) catalysts, UOP's standard procedure for activation and testing was used. The slurry autoclave reactor used for these runs is operated in a hot box which is maintained at 130°C. A schematic of the plant is shown in Figure 1. The hot box traps are maintained at a pressure 5 psi less than the autoclave. Feed is added continuously below the level of liquid in the reactor. Overhead gas is removed continuously from the reactor, the part of it that does not condense in the hot box trap is taken first into a trap which is maintained at 0°C and 50 psig followed by a -78°C trap (atmospheric pressure). Slip streams of the gas leaving the 130°C hot box and the 0°C trap are analyzed with on-line GC analyzers by, respectively, boiling point and gas type analyses. The liquid level in the autoclave is maintained at a constant level by periodic withdrawals of wax. This wax is taken into the train of traps described above.

The autoclave was loaded with 72.7 g of the as received catalyst and 290 g of Ethylflo™ 164 (a C₃₀ oil obtained from the Ethyl Corporation). The catalyst was activated by heating it to 280°C under a nitrogen atmosphere. After pressure testing the plant, the feed syngas blend which is made up of hydrogen, carbon monoxide and argon in the molar ratio 0.7:1.0:0.1 is introduced. Argon is used as an internal standard. The catalyst is then reduced for a period of 12 hr. The syngas feed rate, reactor temperature and pressure were maintained at 2 NL/hr/gFe, 280°C and 153 psig, respectively. During the remainder of the run the feed rate, temperature, and pressure were controlled at 2.4 NL/hr/gFe, 265°C and 290 psig, respectively. In Run 53, as will be discussed below, condition changes were made during the run. These conditions are noted at the top of the figures which summarize the performance of each individual catalyst (See Appendix A).

Run 51

This run used UCI "B" catalyst, its performance is outlined in Figures A-1 to A-6 and material balance at line-out conditions is summarized in Table 2. Unlike the catalyst UCI "A", this catalyst was quite stable. The performance of UCI "A" catalyst was reported in Technical Progress Report No. 6¹. The CO conversion was 60% which is the same as the line-out conversion for UCI "A" catalyst in Run 50. The ultimate selectivities for light products were high, similar to Run 31; however, it took ten days to achieve high light end selectivity.

The H₂:CO usage ratio was about 0.65, which is the highest of the three UCI catalysts. This catalyst produced a higher level of methane than the previous two and also had a lower olefin

to paraffin ratio for the C₂ to C₄ olefins (Figures A-4 to A-6). Both of these observations are consistent with a higher usage ratio. The weights of different products collected in various traps is tabulated in Appendix B, Table B-1.

Even though the selectivities to light products increased markedly during this run (5.9% methane selectivity at line-out, Figure A-4), the H₂:CO usage ratio was consistently at 0.61 to 0.62. Although the catalyst selectivity was obviously changing during this period the CO+H₂ conversion was nearly constant. The effects of the selectivity changes (more methane, more olefins) may have counterbalanced resulting in a stable usage ratio.

After comparing the first three UCI catalysts ("O", "A", and "B") it was decided that the commercial-scale preparation for the LaPorte SBCR test should follow the recipe of the UCI "O" catalyst that was tested in Runs 44 and 48¹. UCI "A" catalyst (Run 50) produced more wax (less methane) than UCI "O" (Run 44 and 48). Although the ultimate performance of UCI "B" catalyst (Run 51) was superior to UCI "O" and "A" (for the objectives of the LaPorte F-T demo run of testing a low wax-producing catalyst), it took ten days in Run 51 to achieve this performance. Since the LaPorte test was going to last about twenty days, a ten day line-out period was considered too long.

Run 53

This run used UCI "Start-up" catalyst. It is a sample from an aliquot that UCI withdrew from the initial several hundred pound portion of their commercial-scale production run of catalyst for the August, 1992 SBCR run at LaPorte, Texas. The composition of this catalyst was not the same as the catalyst from the main part of the catalyst-manufacturing run, UCI "Composite" catalyst. The "Composite" catalyst was loaded into the SBCR at LaPorte and was tested at UOP in Run 54.

The performance of the "Start-up" catalyst is summarized in Figures A-7 to A-12 and material balance for three different conditions is summarized in Tables 3 to 5. Run 53 started at the conditions (265°C, 290 psig, and 2.4 NL/hr/gFe) which had been used for the runs with the Ruhrchemie and UCI "O", "A", and "B" catalysts. However, after the plant had been on stream for 120 hrs a series of condition changes were made to determine catalyst performance under conditions that were planned to be used at LaPorte. During the final part of the run the plant was returned to the initial conditions to find out if the performance had degraded during the run.

At the time of the first condition change at 120 hrs the catalyst appeared to have reached line-out at 63% CO conversion and 3.3 mole% methane selectivity. Decreasing the pressure from 290 to 200 psig resulted in a decrease in conversion to 50% and about a 0.5% increase in the methane selectivity (Table 3). Increasing the feed rate from 2.4 to 5.0 NL/hr/gFe caused 50% loss in conversion and an increase in the methane selectivity of close to 1%. Next the plant pressure was increased to 400 psig at the same high feed rate. This resulted in an increase in CO conversion to 48%, but little change in the methane selectivity (Table 4). Finally, the plant

was brought back to the initial conditions in two steps, first a decrease in the feed rate from 5 to 2.4 NL/hr/gFe and then a decrease in plant pressure (from 400 to 200 psig), the combined effect of which was an increase in conversion to 55 % and a decrease in methane selectivity to 2.1 %. The final step was an increase in plant pressure to 290 psig which brought the conversion back to where it was at 120 hrs; however, the methane selectivity was 3.0 % versus 3.5 % (Table 5). The selectivity to the other light hydrocarbons (C_2 to C_4) also decreased between 120 hrs and the end of the run. Apparently the aging process did not change the conversion but did shift the selectivity towards heavier products. The weight of reactor wax and overhead products collected during various periods of this run are listed in Table B-2.

Run 54

This run used the UCI "Composite" catalyst which is an aliquot of the 800 lb batch of catalyst that was loaded in the LaPorte SBCR. This catalyst was of finer mesh size than other catalysts used in this study. The "Composite" catalyst is believed to have at least some particles < 10 microns.

The activation procedure used for Run 54 was similar to that used for the LaPorte SBCR run; however, it was different from that used in other autoclave runs in support of the LaPorte SBCR demo (Runs 31, 44, 48, 50, 51, and 53). Initially the catalyst was heated in nitrogen to 200°C and then a gas mixture containing 25 % nitrogen and 75 % syngas was used to raise the reactor temperature to 280°C. The reactor pressure was maintained at 150 psig. After 12 hours at 280°C, the pressure, temperature, gas composition, and gas flow rate were changed to bring the reactor to the baseline operating conditions. UOP followed the run plan for the LaPorte run and tested the UCI "Composite" catalyst at four different conditions:

1. baseline (200 psig, 265°C temperature, gas flow rate of 2.5 NL/hr/gFe),
2. high gas flow rate (200 psig, 265°C temperature, gas flow rate of 5.5 NL/hr/gFe),
3. high pressure (400 psig, 265°C temperature, gas flow rate of 5.95 NL/hr/gFe), and
4. baseline-revisited (200 psig, 265°C temperature, gas flow rate of 2.97 NL/hr/gFe).

The feed to the autoclave reactor consists of 6 mole% argon as internal standard so the syngas flow is lower than the total gas flow rate. Also, as will be discussed below, during the run some catalyst was inadvertently lost, and as a result the space velocities are higher than intended.

There were operational problems during this run which were in part due to the small particle size of the catalyst. At approximately 180 HOS, the 0.5 micron filter on the gas outlet line plugged. At the same time the operators were experiencing difficulties with the thermocouple which is used to monitor the temperature change across the gas/liquid interface within the autoclave. Because of this the position of the liquid level was not known, and as a result the liquid level reached the top of the autoclave and might, in fact, have caused the plugging of the gas outlet filter. The normal way of opening a plug, namely back purging with feed failed. This necessitated bypassing the filter, i.e. removing whatever was present in the top of the autoclave without filtering. When the liquid level reached the top of the autoclave it began to

exit through the unfiltered gas outlet line. This resulted in wax and catalyst entering the 130°C trap which normally only accumulates small amount of condensate (liquid) present in the product gas. Figure 2 contains a plot of the amount of material in this trap as a function of time. The overflow apparently began at about 200 HOS when higher than expected weights were recovered from this trap. This was confirmed by the observation that the trap material was not a liquid but a solid wax similar in texture to the wax in the other hot box trap which collects material from the periodic liquid (wax) withdrawals. Detailed data on the products collected during the run in various traps are also listed in Table B-3.

The amount of catalyst lost from the reactor was determined by calcining the recovered wax. The catalyst weights so determined are also plotted in Figure 2. Of the original 72.7 grams of catalyst, 11.4 grams were lost during the time wax overflowed into the hot box trap. By 300 HOS the plant operators were once again able to measure the position of the wax and had re-established the target wax level.

The filters on the wax outlet line functioned during the entire run. This is not too surprising because there are two wax filter assemblies each with two elements, whereas there is only one gas filter assembly and it only has one element (Figure 1). During the LaPorte run the wax outlet filters plugged during the first two hours of use and could not be reopened. However, the flux through the LaPorte wax outlet filters was higher than through the UOP slurry autoclave wax outlet filters.

During the time the plant overflowed condition changes were also being made. The timing of the condition changes and the conversions and product selectivities are in Figures A-13 to A-19. Material balance information for each condition change is also shown in Tables 6 to 9. A problem with the on-line gas analysis resulted in loss of about 225 hr of selectivity data.

The objective in making this UCI catalyst was to make a high- α catalyst, namely one which makes high levels of light products, including methane, and low levels of wax. The initial selectivities illustrate that just the opposite happened and the catalyst produced a very low level of methane. The methane selectivities during this run are compared to methane selectivities in some previous runs on this autoclave plant in Figure 3. The comparison catalysts were all prepared at UOP as part of the current contract as low methane-producing catalysts. It is obvious that the UCI catalyst compares favorably to these previous catalysts as a low methane-producing catalyst.

The initial CO conversion was high, 80%. In addition, the catalyst did not lose any activity up to the first condition change at 200 HOS. This aspect of the performance of the "composite" catalyst was superior to the Ruhrchemie catalyst (Run 31).

Schulz-Flory data from two periods are attached as Figures 4 and 5. The method for obtaining the Schulz-Flory plots was the same as described for Run 48 in Technical Progress Report No. 6¹. The first period analyzed (period 16) covers the time 348-372 HOS. The non-linear regression α_1 and α_2 were, respectively, 0.58 and 0.93. The second period analyzed (period 21)

covered the time 468-492 HOS. The non-linear regression α_1 and α_2 were, respectively, 0.52 and 0.91. It was not possible for one reason or the other to get Schulz-Flory plots for other periods, e.g. missing samples, poor mass balance, etc. The raw GC data from the off-line analyses are attached in Appendix C, Table C-1 to C-6. From these data it is possible to determine, for instance, what fraction of the weight at a carbon number is due to oxygenates. Product distribution for these two periods are plotted in Figures C-1 and C-2.

Each of the above two periods was at the end of a particular set of conditions. Period 16 was at the end of 175 hrs (gas feed rate of 5.0 NL/hr/gFe and 400 psig), whereas period 21 was at the end of 125 hrs (gas feed rate of 2.5 NL/hr/gFe and 200 psig). Throughout both time periods the temperature was 265°C.

Because the operational problems came at 200 hrs, comparisons between Runs 53 and 54 should be made at times before 200 hrs. The final plan for the LaPorte run was to operate at 200 psig pressure, therefore, Run 54 began at this pressure rather than 290 psig. Thus to make a direct comparison between Runs 53 and 54 requires use of Run 53 data after the pressure was decreased to 200 psig at 130 hrs. At this time during Run 53 the CO conversion was 53% and the methane selectivity was 4.0 mole %, compared to 80% CO conversion and about 3.2 mole % during Run 54. Because of the on-line analyzer problems 130 hr selectivity data for Run 54 are obtained by extrapolating 100 hr selectivity data.

One of the apparent findings during this run is catalyst deactivation due to operation at 400 psig. This conclusion is based on the comparison of CO conversion at baseline conditions (50 to 200 HOS, CO conversion: 80%) and baseline-revisited conditions (400 to 500 HOS, CO conversion: 44%). The operating conditions (pressure, temperature, and gas flow rate) were similar during these two periods; however, the space velocity during the baseline-revisited conditions was higher than that during baseline conditions because of the loss in catalyst. Initially 72.7 g catalyst was loaded in the reactor, and at the end of the run it was estimated that 56.3 g (77.4% of the original charge) of catalyst was still in the reactor. CO conversion is found to be linearly proportional to the gas space velocity and one would have expected the CO conversion to drop from 80% to about 62% to account for the catalyst lost from the reactor. However, the observed CO conversion at baseline-revisited conditions was a much lower 44%, leading one to conclude that the catalyst might have deactivated during the high pressure operation. Of the 16.4 g of catalyst lost during the run, 11.4 g was recovered with the wax that overflowed from the reactor and 5 g of catalyst was not accounted for.

The two samples of catalyst from the UCI production run differed both in elemental analysis and performance. The "Composite" sample was more active than the "Start-up" catalyst. The "Composite" also appeared to be the finest mesh of all the UCI catalysts; this might have contributed to its high activity. The fine size probably also contributed to the plugging of the gas filter in the autoclave reactor.

Comparison of Autoclave Performance of UCI Catalysts

Table 10 shows a comparison of the initial (70 HOS) conversions and selectivities obtained for all the catalysts tested at UOP in support of the LaPorte SBCR run. Among all the catalysts, the "Composite" catalyst had the highest conversion (at a lower pressure) and the second lowest $C_1 + C_2$ selectivity. Activities of the UCI catalysts were comparable to the Ruhrchemie catalyst. However, there were differences in composition and selectivity.

The UCI "O" catalyst was prepared to be a copy of the Ruhrchemie catalyst. Composition-wise it was close, deviating mainly in potassium content, 4.1 % for the UCI catalyst vs 1.4 % for the Ruhrchemie catalyst. In spite of this difference the two catalysts showed the same selectivity to methane. There was a difference in the olefinicity of the light ends, the Ruhrchemie catalyst being more prone to hydrogenate olefins and, therefore, giving a more paraffinic product. During line-out the Ruhrchemie catalyst gained conversion whereas the UCI "O" catalyst lost it. At line-out the Ruhrchemie catalyst was a bit more active than the UCI "O" catalyst.

UCI "O" catalyst was evaluated in two separate runs, Run 44 and Run 48. For some reason, perhaps slight unrecorded changes during the two catalyst pre-treatments, the performance during the initial part of the two runs was different. However, the performance difference was not as great as the two runs approached line out.

For the demo run at the LaPorte SBCR reactor there was a concern about the separation of catalyst from the wax. To alleviate catalyst/wax separation problem, catalysts with low selectivity to wax (and, therefore, high methane selectivity) were desirable. UCI catalysts "A" and "B" were prepared to give such product selectivity; however, data from Run 50 and 51 indicated that catalyst "A" produced moderately high wax and catalyst "B" took too long to activate. As a result, a catalyst similar to that tested in Runs 44 and 48 was prepared in large quantities for the LaPorte demo run.

There was considerable variation in the catalyst manufacturing process at UCI during the preparation of the large batch of the catalyst. As a result, samples of catalyst from two batches "start-up" and "composite" were tested in the slurry autoclave Run 53 and Run 54, respectively.

In previous work on this contract with three component (Fe, Cu, K) catalysts, it was found that both the conversion and selectivity were a function of the potassium level. The Ruhrchemie and UCI catalysts were all four component catalysts which contained silicon in addition to the three elements listed above. With these catalysts a relation between performance and potassium level was not observed. It is possible that the silicon forms acid sites which neutralize the effect of potassium and that the effect of potassium on performance is dependent on things such as silicon level and the way silicon and potassium are compounded into the catalyst.

Comparison of the Slurry Autoclave Data with LaPorte SBCR Data

With the assumptions that: (a) the reaction rate is first order with hydrogen concentration and (b) there is no mass transfer resistance in the slurry autoclave, the kinetic parameters were calculated from the data collected in the slurry autoclave pilot plant. Results of these calculations for the four operating conditions of Run 54 are shown in Tables 11 to 14. As discussed before, during Run 54 some catalyst was inadvertently lost. Corrections were made to account for the catalyst that was lost from the reactor but was recovered in the product.

After the reaction rate constant was determined for the "composite" catalyst from the slurry autoclave data, two models were used to calculate the performance of the "composite" catalyst in the LaPorte SBCR:

- a. Model 1 - both the gas and the liquid are assumed to be in plug flow, and
- b. Model 2 - the gas phase is assumed to be in plug flow and the liquid phase assumed to be perfectly mixed.

Bukur's correlation was used to calculate the gas hold-up and Akita-Yoshida correlations were used to calculate the mass transfer coefficients². The liquid phase mixing and volume contraction (α) factor was set at -0.5.

Kinetic information obtained from Run 54 for baseline conditions (Table 11) were used to predict the performance of LaPorte SBCR Run AF-R6.1-A to Run AF-R6.1-H³. The solid concentration in the model calculations was adjusted to match the model column space velocity with the experimental value. A trial and error method was used to calculate hydrogen conversion in the reactor. Once the hydrogen conversion was set, other conversions and productivity numbers were calculated.

Similar procedure was followed to predict the LaPorte SBCR performance in Runs AF-R6.2, AF-R6.3, and AF-R6.4 from the data obtained in Run 54 for high gas flow rate (Table 12), high pressure (Table 13), and baseline-revisited (Table 14) conditions, respectively. A summary of calculations for each run conditions are shown in Tables 15 to 28. The results predicted by the models are compared with the observed SBCR performance in Figures 6 to 3.

Observations and Conclusions

1. In Run AF-R6.1, the loss in CO conversion (Figure 6) with increasing HOS (at the same inlet gas velocity) is due to the continuous loss of catalyst from the reactor.
2. When the gas velocity is doubled from 0.13 fps in Run AF-R6.1 to 0.27 fps in Run AF-R6.2, the conversion drops by almost one-half (Figures 6 and 7). The effect of doubling the reactor pressure from 200 to 400 psig in Run AF-R6.3 is not as pronounced because the conversion from Run AF-R6.2 to Run AF-R6.3 increases by

only about 66%. Previous studies in Fischer-Tropsch synthesis have also observed a non-linear relationship between pressure and conversion.

3. Run AF-R6.1 and AF-R6.4 are carried out under similar pressure, temperature, and gas velocity. However, significant quantities of the catalyst is lost during the run resulting in an increase in the space velocity. The observed performance of catalyst in Run AF-R6.1 and AF-R6.4 almost falls on a straight line which is consistent with the increase in the space velocity. Also, the CO conversion rate obtained at the end of Run AF-R6.1 and Run AF-R6.4 is same. These data would suggest that there was no catalyst deactivation in the SBCR; however, it is hard to say so conclusively. In the LaPorte SBCR, the catalyst was allowed to settle in the wax outside the reactor and then the concentrated catalyst/wax slurry was recirculated back to the reactor. This recirculation will bring "fresh" (less deactivated?) catalyst to the reactor and maintain (or increase) the activity of the catalyst in the reactor.

Plans for Next Quarter

In the next quarter, work with some novel catalysts will be carried out and work on different pretreatment procedures will be initiated.

REFERENCES

1. Frame R. R. and H. B. Gala, Technology Development for Iron Fischer-Tropsch Catalysts, Technical Progress Report No.6, DOE Contract No. DE-AC22-90PC90055.
2. Bechtel Group, Inc., Slurry Reactor Design Studies, Final Report, DOE Contract No. DE-AC22-89PC89867, June 1990.
3. Bhatt, B. L., et al., "Liquid-Phase Fischer-Tropsch Synthesis in a Bubble Column," presented at the DOE Liquefaction Contractor's Review Conference, September 22-24, 1992, Pittsburgh, PA.

FIGURE 1
SCHEMATIC DIAGRAM OF UOP MODIFIED SLURRY AUTOCLAVE PLANT

FIGURE 2
WEIGHT OF WAX AND CATALYST RECOVERED IN RUN 54

**CATALYST CALCINED DURING RECOVERY THERE-
 FORE WGT CAN BE COMPARED TO CAT LOADED
 WHICH WAS 72.7 G**

FIGURE 3
METHANE SELECTIVITY OF VARIOUS F-T IRON CATALYSTS

RUN 49 - OUR BEST

• RUN 43	+ RUN 43 255 DEG C	* RUN 37
□ RUN 54 (100 HRS)	◇ RUN 54 (500 HRS)	× RUN 49

FIGURE 4
SCHULZ-FLORY PRODUCT DISTRIBUTION FOR RUN 54 (PERIOD 16)

FIGURE 5
SCHULZ-FLORY PRODUCT DISTRIBUTION FOR RUN 54 (PERIOD 21)

FIGURE 6

COMPARISON OF CO CONVERSION DATA

FIGURE 7

COMPARISON OF CO+H2 CONVERSION

FIGURE 8

COMPARISON OF CO CONVERSION RATE

TABLE 1
CATALYST CHARACTERISTICS

Catalyst	Ruhrchemie	UCI Catalysts				
		O	A	B	Start-up	Composite
UOP Run Number	31	44 & 48	50	51	53	54
Elemental Analyses (wt %)						
Fe						
Cu	43.8	46.0	60.4	58.9	53.6	54.9
K	2.2	2.3	0.8	0.8	4.0	4.0
Si	4.8	5.3	1.2	2.5	2.3	5.3
	1.4	4.1	0.7	0.8	1.4	3.7
Surface Area, m ² /g	313	232	167	169	136	95
Pore Volume, cc/g	0.53	0.50	0.18	0.20	0.30	0.28

TABLE 2
MATERIAL BALANCE FOR RUN 51 AT 320 HOS

Run No: 51		HOS: 320		Catalyst: UCI "B"	
Catalyst Composition, g/100 g Fe		Operating Conditions		H ₂ /CO Ratios, mole/mole	
		Rx T, C	265	Inlet, I	0.700
Copper	1.34	K	538	Outlet, O	0.750
Potassium	1.32	Rx P, psig	290	Usage, U	0.672
Silicon	4.23	kPa	2101		
Wt of cataly. Rx, g		72.70	Conversion and Selectivity		
Wt of Fe in Rx, g		46.82	CO Conversion		60.0
Wt % Fe in catalyst		64.40	H ₂ Conversion		57.6
Wt of start-up oil, g		290.00	H ₂ +CO Conversion		59.0
Wt of Slurry, g		362.70	Selectivity to CO ₂		47.6
Vol. of Slurry, cm ³		458.69	Selectivity to CH ₄		5.9
Wt % Solids in Rx		20.04	Selectivity to C ₂ H ₆		3.3
Solids Conc., g/cm ³		0.1584945			
Syngas Feed Rate,		Material Balances, mol/hr			
nL/h/gFe	2.256		In	Out	Converted
1E-5 mole/s/gFe	2.796	CO	2.772	1.109	1.663
mol/hr	4.712	H ₂	1.940	0.823	1.117
L/h/gFe	0.214	H ₂ + CO	4.712	1.932	2.780
Water-Gas ft Equilibrium Calculations					
Equm. Cons. K = $\frac{[CO_2][H_2]}{[CO][H_2O]} = \exp[4577.8/T-4.33]$					
K = 65.141		H ₂ O out = 0.009 mol/hr			
mol/hr		Atomic Balance, mol/hr			
CO to CO ₂	0.792	C, in	2.772	H, in	3.881
CO to HC	0.871	Out	2.772	Out	3.881
CO to CH ₄	0.051	as CO ₂	0.792	as H ₂ O	0.018
CO to C ₂ H ₆	0.058	as HC	0.871	as HC	2.216
H ₂ to H ₂ O	0.009	as CO	1.109	as H ₂	1.646
H ₂ to HC	1.108			as HCO	0.071
Mass Balance In g/hr			HCs Distribution, g/hr		
IN		OUT	Methane		0.825
CO	77.641	CO	31.056	Ethane	0.865
H ₂	3.912	H ₂	1.660	Others	12.144
		CO ₂	34.840	Total	13.834
		H ₂ O	0.163		
		HCs	13.834	Product H/C ratio	2.543
TOTAL IN	81.552	OUT	81.552	O/C ratio	0.081
HC Yield	HCs	C1+C2(p)	CO Conversion Rate, gmole/kg Fe/hr		
g/h/gFe	0.295	0.036	Syngas Converted, Nm ³ /hr/m ³ Rx		
g/nL syn	0.131	0.016	STY of C ₃ + in 24 hrs. kg/m ³ Rx		

TABLE 3
MATERIAL BALANCE FOR RUN 53 AT 140 HOS

Run No:	53	HOS:	140	Catalyst:	UCI "START-UP"
Catalyst Composition, g/100 g Fe		Operating Conditions		H ₂ /CO Ratios, mole/mole	
		Rx T, C	265	Inlet, I	0.700
Copper	7.52	K	538	Outlet, O	0.770
Potassium	2.57	Rx P, psig	200	Usage, U	0.621
Silicon	4.29	kPa	1480		
Wt of catalyst in Rx, g		72.70	Conversion and Selectivity		
Wt of Fe in Rx, g		44.15	CO Conversion		49.5
Wt % Fe in catalyst		60.73	H ₂ Conversion		43.9
Wt of start-up oil, g		290.00	H ₂ +CO Conversion		47.2
Wt of Slurry, g		362.70	Selectivity to CO ₂		49.0
Vol. of Slurry, cm ³		458.69	Selectivity to CH ₄		3.8
Wt % Solids in Rx		20.04	Selectivity to C ₂ H ₆		1.2
Solids Conc., g/cm ³		0.1584945			
Syngas Feed Rate,			Material Balances, mol/hr		
nL/h/gFe	2.256			In	Out
1E-5 mole/s/gFe	2.796	CO	2.614	1.320	1.294
mol/hr	4.444	H ₂	1.830	1.026	0.804
L/h/gFe	0.304	H ₂ + CO	4.444	2.346	2.098
Water-Gas Shift Equilibrium Calculations					
Equm. Cons. K = $\frac{[CO_2][H_2]}{[CO][H_2O]} = \exp[4577.8/T-4.33]$					
K =		65 141	H ₂ O out =		0.008 mol/hr
mol/hr			Atomic Balance, mol/hr		
CO to CO ₂	0.634	C, in	2.614	H, in	3.660
CO to HC	0.660	Out	2.614	Out	3.660
CO to CH ₄	0.025	as CO ₂	0.634	as H ₂ O	0.015
CO to C ₂ H ₆	0.016	as HC	0.660	as HC	1.592
H ₂ to H ₂ O	0.008	as CO	1.320	as H ₂	2.053
H ₂ to HC	0.796			as HCO	0.018
Mass Balance in g/hr			HCs Distribution, g/hr		
	IN	OUT			
CO	73.222	CO	36.977	Methane	0.402
H ₂	3.689	H ₂	2.069	Ethane	0.238
		CO ₂	27.905	Others	9.184
		H ₂ O	0.136	Total	9.824
		HCs	9.824		
TOTAL IN	76.911	OUT	76.911	Product H/C ratio	2.412
				O/C ratio	0.028
HC Yield	HCs	C1+C2(p	CO Conversion Rate, gmole/kg Fe/hr		
g/h/gFe	0.223	0.015	Syngas Converted, Nm ³ /hr/m ³ Rx		102
g/nL syn	0.099	0.006	STY of C3+ in 24 hrs, kg/m ³ Rx		481

TABLE 4
MATERIAL BALANCE FOR RUN 53 AT 220 HOS

Run No:	53	HOS:	220	Catalyst:	UCI "START-UP"
Catalyst Composition, g/100 g Fe		Operating Conditions		H2/CO Ratios, mole/mole	
Copper	7.52	Rx T, C	265	Inlet, I	0.700
Potassium	2.57	K	538	Outlet, O	0.820
Silicon	4.29	Rx P, psig	400	Usage, U	0.573
		kPa	2859		
Wt of catalyst in Rx, g			72.70	Conversion and Selectivity	
Wt of Fe in Rx, g			44.15	CO Conversion	48.0
Wt % Fe in catalyst			60.73	H2 Conversion	39.3
Wt of start-up oil, g			290.00	H2+CO Conversion	44.4
Wt of Slurry, g			362.70	Selectivity to CO2	47.0
Vol. of Slurry, cm ^ 3			458.69	Selectivity to CH4	2.9
Wt % Solids in Rx			20.04	Selectivity to C2H6	0.6
Solids Conc. , g/cm ^ 3			0.1584945		
Syngas Feed Rate,			Material Balances, mol/hr		
nL/h/gFe	4.700			In	Out
1E-5 mole/s/gFe	5.825	CO	5.446	2.832	2.614
mol/hr	9.258	H2	3.812	2.316	1.497
L/h/gFe	0.328	H2 + CO	9.258	5.148	4.111
Water-Gas Shift Equilibrium Calculations					
Equm. Cons. K = [CO2][H2]/[CO][H2O] = exp[4577.8/T-4.33]					
K =		65.141	H2O out =		0.015
mol/hr					
Atomic Balance, mol/hr					
CO to CO2	1.229	C, in	5.446	H, in	7.625
CO to HC	1.385	Out	5.446	Out	7.625
CO to CH4	0.040	as CO2	1.229	as H2O	0.031
CO to C2H6	0.017	as HC	1.385	as HC	2.962
H2 to H2O	0.015	as CO	2.832	as H2	4.631
H2 to HC	1.481			as HCO	0.141
Mass Balance in g/hr			HCs Distribution, g/hr		
	IN	OUT	Methane	0.645	
CO	152.547	CO	79.324	Ethane	0.250
H2	7.686	H2	4.668	Others	20.995
		CO2	54.072	Total	21.890
		H2O	0.278		
		HCs	21.890	Product	H/C ratio
TOTAL IN	160.232	OUT	160.232		O/C ratio
HC Yield	HCs	C1+C2(p	CO Conversion Rate, gmole/kg Fe/hr	59	
g/h/gFe	0.496	0.020	Syngas Converted, Nm ^ 3/hr/m ^ 3 Rx	201	
g/nL syn	0.105	0.004	STY of C3+ in 24 hrs, kg/m ^ 3 Rx	1099	

TABLE 5
MATERIAL BALANCE FOR RUN 53 AT 360 HOS

Run No:	53	HOS:	360	Catalyst:	UCI "START-UP"
Catalyst Composition, g/100 g Fe		Operating Conditions		H2/CO Ratios, mole/mole	
		Rx T, C	265	Inlet, I	0.700
Copper	7.52	K	538	Outlet, O	0.800
Potassium	2.57	Rx P, psig	290	Usage, U	0.630
Silicon	4.29	kPa	2101		
Wt of catalyst in Rx, g		72.70	Conversion and Selectivity		
Wt of Fe in Rx, g		44.15	CO Conversion		61.0
Wt % Fe in catalyst		60.73	H2 Conversion		54.9
Wt of start-up oil, g		290.00	H2+CO Conversion		58.5
Wt of Slurry, g		362.70	Selectivity to CO2		48.0
Vol. of Slurry, cm ^ 3		458.69	Selectivity to CH4		3.0
Wt % Solids in Rx		20.04	Selectivity to C2H6		0.7
Solids Conc., g/cm ^ 3		0.1584945			
Syngas Feed Rate,		Material Balances, mol/hr			
nL/h/gFe	2.256		In	Out	Converted
1E-5 mole/s/gFe	2.796	CO	2.614	1.020	1.595
mol/hr	4.444	H2	1.830	0.825	1.005
L/h/gFe	0.214	H2 + CO	4.444	1.844	2.600
Water-Gas Shift Equilibrium Calculations					
Equm. Cons K = [CO2][H2]/[CO][H2O] = exp[4577.8/T-4.33]					
K =		65 141	H2O out =		0.010 mol/hr
mol/hr		Atomic Balance, mol/hr			
CO to CO2	0.765	C, in	2.614	H, in	3.660
CO to HC	0.829	Out	2.614	Out	3.660
CO to CH4	0.025	as CO2	0.765	as H2O	0.019
CO to C2H6	0.012	as HC	0.829	as HC	1.991
H2 to H2O	0.010	as CO	1.020	as H2	1.650
H2 to HC	0.996			as HCO	0.054
Mass Balance in g/hr			HCs Distribution, g/hr		
	IN	OUT			
CO	73.222	CO	28.557	Methane	0.399
H2	3.689	H2	1.663	Ethane	0.175
		CO2	33.686	Others	12.261
		H2O	0.171	Total	12.835
		HCs	12.835	Product H/C ratio	
TOTAL IN	76.911	OUT	76.911	O/C ratio	
HC Yield	HCs	C1+C2(p)	CO Conversion Rate, gmole/kg Fe/hr		36
g/h/gFe	0.291	0.013	Syngas Converted, Nm ^ 3/hr/m ^ 3 Rx		127
g/nL syn	0.129	0.006	STY of C3+ in 24 hrs, kg/m ^ 3 Rx		642

TABLE 6
MATERIAL BALANCE FOR RUN 54 AT 175 HOS

Run No: 54		HOS: 175		Catalyst:		UCI "COMPOSITE"	
Catalyst Composition, g/100 g Fe		Operating Conditions		H2/CO Ratios, mole/mole			
		Rx T, C	265	Inlet, I		0.700	
Copper	7.86	K	538	Outlet, O		1.250	
Potassium	7.86	Rx P, psig	200	Usage, U		0.559	
Silicon	11.02	kPa	1480				
Wt of catalyst in Rx, g		72.70		Conversion and Selectivity			
Wt of Fe in Rx, g		39.12		CO Conversion		79.6	
Wt % Fe in catalyst		53.81		H2 Conversion		63.6	
Wt of start-up charge, g		290.00		H2+CO Conversion		73.0	
Wt of Slurry, g		362.70		Selectivity to CO2		47.0	
Vol. of Slurry, cm ^ 3		458.69		Selectivity to CH4		3.5	
Wt % Solids in Rx		20.04		Selectivity to C2H6		0.7	
Solids Conc. , g/cm ^ 3		0.1584945					
Syngas Feed Rate,		Material Balances, mol/hr					
nL/h/gFe	2.322			In	Out	Converted	
1E-5 mole/s/gFe	2.877	CO		2.384	0.486	1.897	
mol/hr	4.052	H2		1.668	0.608	1.061	
L/h/gFe	0.313	H2 + CO		4.052	1.094	2.958	
Water-Gas Shift Equilibrium Calculations							
Eqm. Cons. K = [CO2][H2]/[CO][H2O] = exp[4577.8/T-4.33]							
K =		65.141		H2O out =		0.017 mol/hr	
mol/hr		Atomic Balance, mol/hr					
CO to CO2	0.892	C, in	2.384	H, in	3.337	O, in	2.384
CO to HC	1.006	Out	2.384	Out	3.337	Out	
CO to CH4	0.035	as CO2	0.892	as H2O	0.034	as H2O	0.017
CO to C2H6	0.014	as HC	1.006	as HC	2.087	as CO2	1.783
H2 to H2O	0.017	as CO	0.486	as H2	1.216	as CO	0.486
H2 to HC	1.044					as HCO	0.097
Mass Balance In g/hr				HCs Distribution, g/hr			
IN		OUT		Methane	0.565		
CO	66.764	CO	13.620	Ethane	0.212		
H2	3.364	H2	1.225	Others	14.953		
		CO2	39.245	Total	15.729		
		H2O	0.308				
		HCs	15.729	Product	H/C ratio	2.076	
TOTAL IN	70.128	OUT	70.128		O/C ratio	0.096	
HC Yield	HCs	C1+C2(p)	CO Conversion Rate, gmole/kg Fe/hr	49			
g/h/gFe	0.402	0.020	Syngas Converted, Nm ^ 3/hr/m ^ 3 Rx	144			
g/nL syn	0.173	0.009	STY of C3+ in 24 hrs, kg/m ^ 3 Rx	782			

TABLE 7
MATERIAL BALANCE FOR RUN 54 AT 240 HOS

Run No:	54	HOS:	240	Catalyst:	UCI "COMPOSITE"
Catalyst Composition, g/100 g Fe		Operating Conditions		H ₂ /CO Ratios, mole/mole	
Copper	7.86	Rx T, C	265	Inlet, I	0.700
Potassium	7.86	K	538	Outlet, O	0.750
Silicon	11.02	Rx P, psig	200	Usage, U	0.640
		kPa	1480		
Wt of catalyst in Rx, g		65.70	Conversion and Selectivity		
Wt of Fe in Rx, g		35.35	CO Conversion		45.0
Wt % Fe in catalyst		53.81	H ₂ Conversion		41.1
Wt of start-up oil, g		290.00	H ₂ +CO Conversion		43.4
Wt of Slurry, g		355.70	Selectivity to CO ₂		48.0
Vol. of Slurry, cm ³		456.43	Selectivity to CH ₄		3.9
Wt % Solids in Rx		18.47	Selectivity to C ₂ H ₆		0.2
Solids Conc., g/cm ³		0.14394229			
Syngas Feed Rate,			Material Balances, mol/hr		
nL/h/gFe	5.201		In	Out	Converted
1E-5 mole/s/gFe	6.445	CO	4.825	2.654	2.171
mol/hr	8.202	H ₂	3.377	1.989	1.389
L/h/gFe	0.701	H ₂ + CO	8.202	4.643	3.560
Water-Gas Shift Equilibrium Calculations					
Eqm. Cons. K = $\frac{[CO_2][H_2]}{[CO][H_2O]} = \exp[4577.8/T-4.33]$					
K =		65.141	H ₂ O out =		0.012 mol/hr
mol/hr			Atomic Balance, mol/hr		
CO to CO ₂	1.042	C, in	4.825	H, in	6.755
CO to HC	1.129	Out	4.825	Out	6.755
CO to CH ₄	0.044	as CO ₂	1.042	as H ₂ O	0.024
CO to C ₂ H ₆	0.005	as HC	1.129	as HC	2.753
H ₂ to H ₂ O	0.012	as CO	2.654	as H ₂	3.978
H ₂ to HC	1.377			as HCO	0.075
Mass Balance in g/hr			HCs Distribution, g/hr		
	IN	OUT	Methane		0.706
CO	135.150	CO	Ethane		0.068
H ₂	6.809	H ₂	Others		16.760
		CO ₂	Total		17.534
		H ₂ O			
		HCs	Product H/C ratio		2.439
TOTAL IN	141.959	OUT	O/C ratio		0.066
HC Yield	HCs	C1+C2(p)	CO Conversion Rate, gmole/kg Fe/hr		61
g/h/gFe	0.496	0.022	Syngas Converted, Nm ³ /hr/m ³ Rx		175
g/nL syn	0.095	0.004	STY of C3+ in 24 hrs, kg/m ³ Rx		881

TABLE 8
MATERIAL BALANCE FOR RUN 54 AT 360 HOS

Run No: 54		HOS: 360		Catalyst:		UCI "COMPOSITE"	
Catalyst Composition, g/100 g Fe		Operating Conditions		H2/CO Ratios, mole/mole			
		Rx T, C	265				
Copper	7.86	K	538	Inlet, I	0.700		
Potassium	7.86	Rx P, psig	400	Outlet, O	0.780		
Silicon	11.02	kPa	2859	Usage, U	0.621		
Wt of catalyst in Rx, g		61.15		Conversion and Selectivity			
Wt of Fe in Rx, g		32.90		CO Conversion		54.2	
Wt % Fe in catalyst		53.81		H2 Conversion		48.9	
Wt of start-up oil, g		290.00		H2+CO Conversion		52.0	
Wt of Slurry, g		351.15		Selectivity to CO2		37.5	
Vol. of Slurry, cm ^ 3		454.97		Selectivity to CH4		2.6	
Wt % Solids in Rx		17.41		Selectivity to C2H6		0.5	
Solids Conc., g/cm ^ 3		0.13440589					
Syngas Feed Rate,		Material Balances, mol/hr					
nL/h/gFe	2.626			In	Out	Converted	
1E-5 mole/s/gFe	3.255	CO		2.268	1.039	1.229	
mol/hr	3.855	H2		1.587	0.812	0.776	
L/h/gFe	0.183	H2 + CO		3.855	1.850	2.005	
Water-Gas Shift Equilibrium Calculations							
Eqm. Cons K =		$[CO_2][H_2]/[CO][H_2O] = \exp[4577.8/T-4.33]$					
K =		65.141		H2O out =		0.006 mol/hr	
mol/hr		Atomic Balance, mol/hr					
CO to CO2	0.461	C, in	2.268	H, in	3.175	O, in	2.268
CO to HC	0.768	Out	2.268	Out	3.175	Out	
CO to CH4	0.020	as CO2	0.461	as H2O	0.011	as H2O	0.006
CO to C2H6	0.008	as HC	0.768	as HC	1.540	as CO2	0.922
H2 to H2O	0.006	as CO	1.039	as H2	1.624	as CO	1.039
H2 to HC	0.770					as HCO	0.302
Mass Balance in g/hr				HCs Distribution, g/hr			
IN		OUT		Methane		0.320	
CO	63.520	CO	29.092	Ethane		0.115	
H2	3.200	H2	1.637	Others		15.171	
		CO2	20.285	Total		15.607	
		H2O	0.100				
		HCs	15.607				
TOTAL IN	66.721	OUT	66.721	Product	H/C ratio	2.005	
					O/C ratio	0.393	
HC Yield	HCs	C1+C2(p	CO Conversion Rate, gmole/kg Fe/hr		37		
g/h/gFe	0.474	0.013	Syngas Converted, Nm ^ 3/hr/m ^ 3 Rx		99		
g/nL syn	0.181	0.005	STY of C3+ in 24 hrs, kg/m ^ 3 Rx		800		

TABLE 9
MATERIAL BALANCE FOR RUN 54 AT 500 HOS

Run No: 54		HOS: 500		Catalyst:		UCI "COMPOSITE"	
Catalyst Composition, g/100 g Fe		Operating Conditions		H2/CO Ratios, mole/mole			
		Rx T, C	265	Inlet, I		0.700	
Copper	7.86	K	538	Outlet, O		0.770	
Potassium	7.86	Rx P, psig	200	Usage, U		0.604	
Silicon	11.02	kPa	1480				
Wt of catalyst in Rx, g			61.15	Conversion and Selectivity			
Wt of Fe in Rx, g			32.90	CO Conversion		42.4	
Wt % Fe in catalyst			53.81	H2 Conversion		36.6	
Wt of start-up oil, g			290.00	H2+CO Conversion		40.0	
Wt of Slurry, g			351.15	Selectivity to CO2		44.0	
Vol. of Slurry, cm ^ 3			454.97	Selectivity to CH4		3.9	
Wt % Solids in Rx			17.41	Selectivity to C2H6		0.6	
Solids Conc., g/cm ^ 3			0.13440589				
Syngas Feed Rate,			Material Balances, mol/hr				
nL/h/gFe	2.794			In	Out	Converted	
1E-5 mole/s/gFe	3.463	CO		2.412	1.390	1.023	
mol/hr	4.101	H2		1.689	1.071	0.618	
L/h/gFe	0.377	H2 + CO		4.101	2.461	1.640	
Water-Gas Shift Equilibrium Calculations							
Equm. Cons. K = [CO2][H2]/[CO][H2O] = exp[4577.8/T-4.33]							
K =		65.141	H2O out =		0.005	mol/hr	
mol/hr		Atomic Balance, mol/hr					
CO to CO2	0.450	C, in	2.412	H, in	3.377	O, in	2.412
CO to HC	0.573	Out	2.412	Out	3.377	Out	
CO to CH4	0.022	as CO2	0.450	as H2O	0.011	as H2O	0.005
CO to C2H6	0.007	as HC	0.573	as HC	1.225	as CO2	0.900
H2 to H2O	0.005	as CO	1.390	as H2	2.142	as CO	1.390
H2 to HC	0.612					as HCO	0.117
Mass Balance in g/hr				HCs Distribution, g/hr			
	IN		OUT	Methane		0.358	
CO	67.575	CO	38.923	Ethane		0.103	
H2	3.405	H2	2.159	Others		9.531	
		CO2	19.808	Total		9.993	
		H2O	0.096				
		HCs	9.993	Product H/C ratio		2.138	
TOTAL IN	70.979	OUT	70.979	O/C ratio		0.205	
HC Yield	HCs	C1+C2(p)	CO Conversion Rate, gmole/kg Fe/hr		31		
g/h/gFe	0.304	0.014	Syngas Converted, Nm ^ 3/hr/m ^ 3 Rx		81		
g/nL syn	0.109	0.005	STY of C3+ in 24 hrs. kg/m ^ 3 Rx		503		

TABLE 10
SUMMARY PERFORMANCE DATA FOR RUHRCHEMIE AND UCI CATALYSTS

CONDITIONS:

200 OR 290 PSIG
265°C

2.4 NI/hr/g Fe
 $H_2:CO$ (FEED) = 0.7

Catalyst	Run Number	Conversion, %		$H_2:CO$ Usage Ratio	Selectivity, %			
		CO	$CO+H_2$		C_1	C_2	C_3	CO_2
Ruhrchemie	31 ¹	70	68	0.70	4.0	1.8	1.9	43
UCI "O"	44 ¹	78	70	0.58	3.6	0.90	2.4	48
UCI "O"	48 ¹	70	65	0.62	5.4 ³	2.4	3.5	45
UCI "A"	50 ¹	70	65	0.56	2.7	0.75	2.2	46
UCI "B"	51 ¹	56	57	0.65	3.1 ⁴	1.8	2.8	45
Start-up	53 ¹	70	60	0.54	3.6	1.3	3.3	50
Composite	54 ²	80	75	0.55	3.2	0.6	2.3	47
1. 290 psig 2. 200 psig 3. Ultimate line-out selectivity = 6.5% 4. Ultimate line-out selectivity = 6.0%								

TABLE 11
KINETIC PARAMETERS FOR RUN 54 AT 175 HOS

Catalyst Composition, g/100 g Fe		Operating Conditions	
Copper		Reactor T, C	265
Potassium		K	538
Silicon		Reactor P, psig	200
		kPa	1480
Wt of catalyst, g	72.70	Syngas Feed Rate,	
Wt of Fe in Rx, g	39.12	nL/h/gFe	2.322
Wt % Fe in catalyst	53.81	1E-5 mole/s/gFe	2.877
Wt of start-up oil, g	290.00	mol/hr	4.052
Volume of Slurry, cm ³	458.69	L/h/gFe	0.313
Wt % Solids in Rx	20.04		
Volume % Solids in Rx	5.11		
H2/CO Ratios, mole/mole		Conversion and Selectivity	
Inlet, I		CO Conversion	79.6
Outlet, O		H2 Conversion	63.6
Usage, U		H2+ CO Conversion	73.0
		Selectivity to CO2	47.0
		Selectivity to CH4	3.5
		Selectivity to C2H6	0.7

Alpha	-0.500
Alpha*	-0.574
Da	3.090
Henry's Constant, Pa*m ³ /mol	25979
Rate Parameter, kp 1E-11 mol/s/g Fe/Pa	6.01
Reaction Rate, -r(CO+H2) 1E-5 mol/s/gFe	2.10
1E-5 mol/s	82.17
Rate Constant, 1E-3 m ³ /kg Fe/s	0.5596

TABLE 12
KINETIC PARAMETERS FOR RUN 54 AT 240 HOS

Catalyst Composition, g/100 g Fe		Operating Conditions	
Copper	7.86	Reactor T, C	265
Potassium	7.86	K	538
Silicon	11.02	Reactor P, psig	200
		kPa	1480
Wt of catalyst, g	65.70	Syngas Feed Rate,	
Wt of Fe in Rx, g	35.35	nL/h/gFe	5.201
Wt % Fe in catalyst	53.81	1E-5 mole/s/gFe	6.445
Wt of start-up oil, g	290.00	mol/hr	8.202
Volume of Slurry, cm ³	456.43	L/h/gFe	0.701
Wt % Solids in Rx	18.47		
Volume % Solids in Rx	4.64		
H2/CO Ratios, mole/mole		Conversion and Selectivity	
Inlet, I	0.700	CO Conversion	45.0
Outlet, O	0.750	H2 Conversion	41.1
Usage, U	0.640	H2+CO Conversion	43.4
		Selectivity to CO2	48.0
		Selectivity to CH4	3.9
		Selectivity to C2H6	0.2

Alpha	-0.500
Alpha*	-0.528
Da	1.401
Henry's Constant, Pa*m ³ /mol	25979
Rate Parameter, kp 1E-11 mol/s/g Fe/Pa	6.10
Reaction Rate, -r(CO+H2) 1E-5 mol/s/gFe	2.80
1E-5 mol/s	98.89
Rate Constant, 1E-3 m ³ /kg Fe/s	0.6184

TABLE 13
KINETIC PARAMETERS FOR RUN 54 AT 360 HOS

Catalyst Composition, g/100 g Fe		Operating Conditions	
		Reactor T, C	265
Copper	7.86	K	538
Potassium	7.86	Reactor P, psig	400
Silicon	11.02	kPa	2859
Wt of catalyst, g	61.15	Syngas Feed Rate,	
Wt of Fe in Rx, g	32.90	nL/h/gFe	5.588
Wt % Fe in catalyst	53.81	1E-5 mole/s/gFe	6.925
Wt of start-up oil, g	290.00	mol/hr	8.202
Volume of Slurry, cm ³	454.97	L/h/gFe	0.390
Wt % Solids in Rx	17.41		
Volume % Solids in Rx	4.34		
H ₂ /CO Ratios, mole/mole		Conversion and Selectivity	
		CO Conversion	54.2
Inlet, I	0.700	H ₂ Conversion	48.9
Outlet, O	0.780	H ₂ +CO Conversion	52.0
Usage, U	0.631	Selectivity to CO ₂	37.5
		Selectivity to CH ₄	2.6
		Selectivity to C ₂ H ₆	0.5

Alpha	-0.500
Alpha*	-0.532
Da	1.827
Henry's Constant, Pa*m ³ /mol	25979
Rate Parameter, kp 1E-11 mol/s/g Fe/Pa	4.43
Reaction Rate, -r(CO+H ₂) 1E-5 mol/s/gFe	3.60
1E-5 mol/s	118.48
Rate Constant, 1E-3 m ³ /kg Fe/s	0.4448

TABLE 14
KINETIC PARAMETERS FOR RUN 54 AT 500 HOS

Catalyst Composition, g/100 g Fe		Operating Conditions	
		Reactor T, C	265
Copper	7.86	K	538
Potassium	7.86	Reactor P, psig	200
Silicon	11.02	kPa	1480
Wt of catalyst, g	61.15	Syngas Feed Rate,	
Wt of Fe in Rx, g	32.90	nL/h/gFe	2.794
Wt % Fe in catalyst	53.81	1E-5 mole/s/gFe	3.463
Wt of start-up oil, g	290.00	mol/hr	4.101
Volume of Slurry, cm ³	454.97	L/h/gFe	0.377
Wt % Solids in Rx	17.41		
Volume % Solids in Rx	4.34		
H2/CO Ratios, mole/mole		Conversion and Selectivity	
		CO Conversion	42.4
Inlet, I	0.700	H2 Conversion	36.6
Outlet, O	0.770	H2 + CO Conversion	40.0
Usage, U	0.604	Selectivity to CO2	44.0
		Selectivity to CH4	3.9
		Selectivity to C2H6	0.6

Alpha	-0.500
Alpha*	-0.547
Da	1.225
Henry's Constant, Pa*m ³ /mol	25979
Rate Parameter, kp 1E-11 mol/s/g Fe/Pa	2.87
Reaction Rate, -r(CO+H2) 1E-5 mol/s/gFe	1.39
1E-5 mol/s	45.57
Rate Constant, 1E-3 m ³ /kg Fe/s	0.2803

TABLE 15
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-A

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	16.6	83.4	100
Density, g/cm ³	3.100	0.866	0.788
Volume % Solids	4.10	95.90	100.00
Viscosity, g/cm/s	-	0.0225	0.0308
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.40
Catalyst Weight, kg	178.6
Cat. Loading, kg/m ³	127.2

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.0
Feed Rate, am ³ /hr	36.6
nm ³ /hr	271.3
SV, am ³ /hr/m ³	26.1
nm ³ /hr/m ³	193.2
nm ³ /h/kg Fe	2.82
Corr. factor for kLa	0.587
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-A		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	61.9	60.5	67.0
Ug, cm/sec		2.6	2.7
Gas hold-up, eps-g	0.094	0.101	0.103
kLa (uncorr), 1/s		0.287	0.292
kLa (corr), 1/s		0.168	0.171
kr, epsl, 1/s		0.036	0.038
KR(=kr,epsl.R.T/He)		0.007	0.007
KM(=kLa.R.T/He)		0.029	0.029
K(=KR.KM/(KR+KM))		0.005	0.005
H2+CO Conversion, %	72.4	69.5	65.5
CO Conversion, %	60.2	75.8	71.4
STY, nm ³ /h/m ³		134.2	126.5
STY, nm ³ /h/kg Fe		1.96	1.85
Mass Transfer Res., %		18.55	18.27
CO Conv., gmole/kg Fe/h	53.0	56.14	52.91
-CH2 produced, g/kg Fe/h		417.35	393.38
g/nm ³ syngas		147.80	139.32

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 16
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-B

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	18.2	83.8	100
Density, g/cm ³	3.100	0.868	0.763
Volume % Solids	3.99	96.01	100.00
Viscosity, g/cm/s	-	0.0225	0.0305
Surface Tension, N/m	-	18.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.88
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.37
Catalyst Weight, kg	169.6
Cat. Loading, kg/m ³	123.7

OPERATING CONDITIONS	
Rx Temperature, K	638
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.0
Feed Rate, am ³ /hr	36.6
nm ³ /hr	271.3
SV, am ³ /hr/m ³	26.7
nm ³ /hr/m ³	197.9
nm ³ /h/kg Fe	2.97
Corr. factor for kLa	0.589
H ₂ Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-B		
	Plant	MODEL 1	MODEL 2
H ₂ Conversion, %	60.8	58.5	55.4
U _g , cm/sec		2.6	2.7
Gas hold-up, eps-g	0.127	0.102	0.104
kLa (uncorr), 1/s		0.269	0.294
kLa (corr), 1/s		0.170	0.173
kr, epsl, 1/s		0.037	0.037
KR(=kr,epsl.R.T./He)		0.006	0.006
KM(=kLa.R.T./He)		0.029	0.030
K(=KR KM/(KR+KM))		0.005	0.005
H ₂ +CO Conversion, %	68.4	67.2	63.7
CO Conversion, %	73.8	73.2	69.4
STY, nm ³ /h/m ³		132.9	126.0
STY, nm ³ /h/kg Fe		2.00	1.89
Mass Transfer Res., %		17.93	17.70
CO Conv., gmole/kg Fe/h	57.0	57.16	54.17
CH ₂ produced, g/kg Fe/h		424.94	402.73
g/nm ³ syngas		142.92	135.45

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 17
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-C

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	18.43	84.57	100
Density, g/cm ³	3.100	0.866	0.758
Volume % Solids	3.77	96.23	100.00
Viscosity, g/cm/s	-	0.0225	0.0300
Surface Tension, N/m	-	16.5	-
Part Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	164.6
Cat Loading kg/m ³	117.0

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.0
Feed Rate, am ³ /hr	36.6
nm ³ /hr	271.3
SV, am ³ /hr/m ³	26.0
nm ³ /hr/m ³	192.8
nm ³ /h/kg Fe	3.06
Corr. factor for kLa	0.593
H2 Diffusivity cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-C		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	53.0	57.7	54.8
Ug, cm/sec		2.7	2.7
Gas hold-up, eps-g	0.134	0.103	0.104
kLa (uncorr), 1/s		0.290	0.295
kLa (corr), 1/s		0.172	0.175
kr, epsl, 1/s		0.035	0.035
KR(=kr,epsl.R.T/He)		0.006	0.006
KM(=kLa.R.T/He)		0.030	0.030
K(=KR.KM/(KR+KM))		0.005	0.005
H2+CO Conversion, %	58.7	66.2	62.7
CO Conversion, %	62.7	72.2	68.4
STY, nm ³ /h/m ³		127.7	120.9
STY, nm ³ /h/kg Fe		2.03	1.92
Mass Transfer Res., %		16.99	16.77
CO Conv., gmole/kg Fe/h	52.5	58.04	54.98
-CH2 produced, g/kg Fe/h		431.47	408.76
g/nm ³ syngas		140.86	133.45

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 18
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-D

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	14.35	85.65	100
Density, g/cm ³	3.100	0.886	0.751
Volume % Solids	3.48	96.52	100.00
Viscosity, g/cm/s	-	0.0225	0.0293
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	151.7
Cat. Loading, kg/m ³	107.8

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	3.7
Feed Rate, am ³ /hr	33.8
nm ³ /hr	250.5
SV, am ³ /hr/m ³	24.0
nm ³ /hr/m ³	178.0
nm ³ /h/kg Fe	3.07
Corr. factor for kLa	0.597
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-D		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	54.7	57.8	54.8
Ug, cm/sec		2.4	2.5
Gas hold-up, eps-g	0.121	0.098	0.099
kLa (uncorr), 1/s		0.276	0.280
kLa (corr), 1/s		0.165	0.168
kr,epsl, 1/s		0.032	0.032
KR(=kr,epsl.R.T.He)		0.006	0.006
KM(=kLa.R.T/He)		0.028	0.029
K(=KR.KM/(KR+KM))		0.005	0.005
H2+CO Conversion, %	60.7	66.4	62.7
CO Conversion, %	65.0	72.4	68.4
STY, nm^3/h/m^3		118.2	111.7
STY, nm^3/h/kg Fe		2.04	1.93
Mass Transfer Res., %		16.45	16.23
CO Conv., gmole/kg Fe/h	54.8	58.34	55.11
-CH2 produced, g/kg Fe/h		433.74	409.72
g/nm^3 syngas		141.30	133.48

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 19
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-E

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	14.03	85.97	100
Density, g/cm ³	3.100	0.886	0.749
Volume % Solids	3.39	96.61	100.00
Viscosity, g/cm/s	-	0.0225	0.0291
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	147.9
Cat. Loading kg/m ³	105.1

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.3
Feed Rate, am ³ /hr	39.4
nm ³ /hr	292.2
SV, am ³ /hr/m ³	28.0
nm ³ /hr/m ³	207.6
nm ³ /h/kg Fe	3.67
Corr. factor for kLa	0.599
H ₂ Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-E		
	Plant	MODEL 1	MODEL 2
H ₂ Conversion, %	46.0	61.2	49.1
U _g , cm/sec		3.0	3.1
Gas hold-up, eps-g	0.137	0.110	0.111
kLa (uncorr), 1/s		0.314	0.317
kLa (corr), 1/s		0.188	0.190
kr, epsl, 1/s		0.032	0.032
KR(=kr,epsl R.T./He)		0.005	0.005
KM(=kLa R.T./He)		0.032	0.033
K(=KR KM/(KR+KM))		0.005	0.005
H ₂ +CO Conversion, %	50.5	58.8	56.4
CO Conversion, %	53.7	64.1	61.5
STY, nm ³ /h/m ³		122.1	117.0
STY, nm ³ /h/kg Fe		2.16	2.07
Mass Transfer Res., %		14.42	14.29
CO Conv., gmole/kg Fe/h	54.7	61.80	59.24
CH ₂ produced, g/kg Fe/h		459.45	440.45
g/nm ³ syngas		125.08	119.91

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 20
COMPARISON WITH LAPORTE SBC RUN AF-R6.1-

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	12.4	87.6	100
Density, g/cm ³	3.100	0.866	0.738
Volume % Solids	2.95	97.05	100.00
Viscosity, g/cm/s	-	0.0225	0.0282
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	Laporte
ID of Rx, cm	57.2
L of Rx, cm	809.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	128.8
Cat. Loading, kg/m ³	91.5

OPERATING CONDITIONS	
Rx Temperature, K	636
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.0
Feed Rate, am ³ /hr	36.6
nm ³ /hr	271.3
SV, am ³ /hr/m ³	26.0
nm ³ m ³	192.8
nm ³ /h, kg Fe	3.91
Corr. factor for kLa	0.605
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-F		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	45.4	49.2	47.2
Ug, cm/sec		2.8	2.9
Gas hold-up, eps-g	0.136	0.106	0.107
kLa (uncorr), 1/s		0.302	0.305
kLa (corr), 1/s		0.183	0.184
kr, epsl, 1/s		0.028	0.028
KR(=kr, epsl.R.T/He)		0.005	0.005
KM(=kLa.R.T/He)		0.031	0.032
K(=KR.KM/(KR+KM))		0.004	0.004
H2 + CO Conversion, %	49.6	56.5	54.2
CO Conversion, %	52.5	61.6	59.1
STY, nm ³ /h/m ³		108.9	104.5
STY, nm ³ /h/kg Fe		2.21	2.12
Mass Transfer Res., %		13.11	13.00
CO Conv., gmole/kg Fe/h	59.0	63.29	60.71
CH2 produced, g/kg Fe/h		470.53	451.36
g/nm ³ syngas		120.20	115.30

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 21
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-G

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	12.45	87.55	100
Density, g/cm ³	3.100	0.866	0.739
Volume % Solids	2.97	97.03	100.00
Viscosity, g/cm/s	-	0.0225	0.0282
Surface Tension, N/m	-	18.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.30
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	129.4
Cat. Loading, kg/m ³	91.9

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.3
Feed Rate, am ³ /hr	39.4
nm ³ /hr	292.2
SV, am ³ /hr/m ³	28.0
nm ³ /hr/m ³	207.6
nm ³ /h/kg Fe	4.20
Corr. factor for kLa	0.605
H ₂ Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-G		
	Model	MODEL 1	MODEL 2
H ₂ Conversion, %	41.6	48.7	45.1
U _g , cm/sec		3.1	3.2
Gas hold-up, eps-g	0.137	0.112	0.113
kLa (uncorr), 1/s		0.320	0.323
kLa (corr), 1/s		0.193	0.195
kr, epsl, 1/s		0.028	0.028
KR(=kr, epsl, R.T./He)		0.005	0.005
KM(=kLa.R.T./He)		0.033	0.034
K(=KR KM/(KR+KM))		0.004	0.004
H ₂ +CO Conversion, %	44.5	53.6	51.7
CO Conversion, %	46.6	58.5	56.4
STY, nm ³ /h/m ³		111.3	107.4
STY, nm ³ /h/kg Fe		2.25	2.17
Mass transfer Res., %		12.52	12.43
CO Conv., gmole/kg Fe/h	56.5	64.41	62.14
-CH ₂ produced, g/kg Fe/h		478.84	462.00
g/nm ³ syngas		114.09	110.08

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 22
COMPARISON WITH LAPORTE SBCR RUN AF-R6.1-H

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	11.6	88.4	100
Density, g/cm ³	3.100	0.866	0.733
Volume % Solids	2.74	97.26	100.00
Viscosity, g/cm/s	-	0.0225	0.0277
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	119.7
Cat. Loading kg/m ³	85.0

OPERATING CONDITIONS	
Rx Temperature, K	838
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.3
Feed Rate, am ³ /hr	39.4
nm ³ /hr	292.2
SV, am ³ /hr/m ³	28.0
nm ³ /hr/m ³	207.6
nm ³ /h/kg Fe	4.54
Corr. factor for kLa	0.607
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.1-H		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	36.4	44.2	42.7
Ug, cm/sec		3.2	3.2
Gas hold-up, eps-g	0.143	0.113	0.114
kLa (uncorr), 1/s		0.323	0.326
kLa (corr), 1/s		0.196	0.198
kr, epsl, 1/s		0.026	0.026
KR(= kr, epsl, R.T./He)		0.004	0.004
KM(= kLa.R.T./He)		0.034	0.034
K(= KR.KM/(KR+KM))		0.004	0.004
H2+CO Conversion, %	40.9	50.6	49.1
CO Conversion, %	42.5	55.3	53.5
STY, nm ³ /h/m ³		105.4	101.9
STY, nm ³ /h/kg Fe		2.30	2.23
Mass Transfer Res., %		11.53	11.46
CO Conv., gmole/kg Fe/h	57.2	65.91	63.72
-CH2 produced, g/kg Fe/h		490.01	473.73
g/nm ³ syngas		107.98	104.39

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 23
COMPARISON WITH LAPORTE SBCR RUN AF-R6.2-A

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	10.49	89.51	100
Density, g/cm ³	3.100	0.666	0.726
Volume % Solids	2.46	97.54	100.00
Viscosity, g/cm/s	-	0.0225	0.0271
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, in ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	107.2
Cat. Loading, kg/m ³	76.2

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	8.2
Feed Rate, am ³ /hr	76.0
nm ³ /hr	563.6
SV, am ³ /hr/m ³	54.0
nm ³ /hr/m ³	400.4
nm ³ /h/kg Fe	9.77
Corr. factor for kLa	0.611
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.2-A		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	22.3	25.2	25.0
Ug, cm/sec		7.1	7.1
Gas hold-up, eps-g	0.265	0.178	0.178
kLa (uncorr), 1/s		0.531	0.531
kLa (corr), 1/s		0.324	0.324
kr,epsl, 1/s		0.025	0.025
KR(=kr,epsl.R.T./He)		0.004	0.004
KM(=kL.a.R.T./He)		0.056	0.056
K(=KR.KM/(KR+KM))		0.004	0.004
H2+CO Conversion, %	21.1	26.6	26.4
CO Conversion, %	20.2	27.6	27.4
STY, nm ^3/h/m ^3		106.5	105.7
STY, nm ^3/h/kg Fe		2.60	2.58
Mass Transfer Res., %		7.25	7.25
CO Conv., gmole/kg Fe/h	67.1	70.72	70.19
-CH2 produced, g/kg Fe/h		515.87	512.00
g/nm ^3 syngas		52.80	52.40

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 24
COMPARISON WITH LAPORTE SBCR RUN AF-R6.2-B

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	9.45	90.55	100
Density, g/cm ³	3.100	0.666	0.720
Volume % Solids	2.19	97.81	100.00
Viscosity, g/cm/s	-	0.0225	0.0266
Surface Tension, N/m	-	16.5	-
Part Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	95.7
Cat. Loading, kg/m ³	68.0

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	8.2
Feed Rate, am ³ /hr	76.0
nm ³ /hr	563.6
SV, am ³ /hr/m ³	54.0
nm ³ /hr/m ³	400.4
nm ³ /h/kg Fe	10.94
Corr. factor for kLa	0.613
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.2-B		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	19.4	22.9	22.7
Ug, cm/sec		7.2	7.2
Gas hold-up, eps-g	0.25	0.179	0.179
kLa (uncorr), 1/s		0.535	0.535
kLa (corr), 1/s		0.328	0.328
kr, epsl, 1/s		0.023	0.023
KR(=kr.epsl.R.T./He)		0.004	0.004
KM(=kL.a.R.T./He)		0.056	0.056
K(=KR.KM/(KR+KM))		0.004	0.004
H2+CO Conversion, %	18.2	24.2	24.0
CO Conversion, %	17.3	25.1	24.9
STY, nm ³ /h/m ³		96.8	96.0
STY, nm ³ /h/kg Fe		2.65	2.62
Mass Transfer Res., %		6.46	6.45
CO Conv., gmole/kg Fe/h	61.9	71.98	71.41
-CH2 produced, g/kg Fe/h		525.01	520.89
g/nm ³ syngas		47.98	47.60

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 25
COMPARISON WITH LAPORTE SBCR RUN AF-R6.3-A

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	8.44	91.56	100
Density, g/cm ³	3.100	0.666	0.714
Volume % Solids	1.94	98.06	100.00
Viscosity, g/cm/s	-	0.0225	0.0261
Surface Tension, N/m	-	16.5	-
Part. Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	84.8
Cat. Loading, kg/m ³	60.2

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	2859
Inlet Gas Vel., cm/s	4.3
Feed Rate, am ³ /hr	39.4
nm ³ /hr	564.4
SV, am ³ /hr/m ³	28.0
nm ³ /hr/m ³	401.0
nm ³ /h/kg Fe	12.38
Corr. factor for kLa	0.615
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.3-A		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	32.0	27.7	26.9
Ug, cm/sec		3.6	3.7
Gas hold-up, eps-g	0.208	0.121	0.122
kLa (uncorr), 1/s		0.350	0.351
kLa (corr), 1/s		0.215	0.216
kr, epsl, 1/s		0.014	0.014
KR(=kr.epsl.R.T/He)		0.002	0.002
KM(=kL.a.R.T/He)		0.037	0.037
K(=KR.KM/(KR+KM))		0.002	0.002
H2+CO Conversion, %	30.2	29.5	28.7
CO Conversion, %	28.8	30.7	29.9
STY, nm ³ /h/m ³		118.2	115.0
STY, nm ³ /h/kg Fe		3.65	3.55
Mass Transfer Res., %		6.28	6.27
CO Conv., gmole/kg Fe/h	111.2	99.81	97.05
-CH2 produced, g/kg Fe/h		874.98	850.83
g/nm ³ syngas		70.70	68.75

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 26
COMPARISON WITH LAPORTE SBCR RUN AF-R6.3-B

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	7.99	92.01	100
Density, g/cm ³	3.100	0.666	0.711
Volume % Solids	1.83	98.17	100.00
Viscosity, g/cm/s	-	0.0225	0.0259
Surface Tension, N/m	-	16.5	-
Part Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	79.9
Cat Loading, kg/m ³	56.8

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	2859
Inlet Gas Vel., cm/s	4.3
Feed Rate, am ³ /hr	39.4
nm ³ /hr	564.4
SV, am ³ /hr/m ³	28.0
nm ³ /hr/m ³	401.5
nm ³ /h/kg Fe	13.14
Corr. factor for kLa	0.615
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.3-B		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	30.1	26.3	25.6
Ug, cm/sec		3.7	3.7
Gas hold-up, eps-g	0.221	0.122	0.122
kLa (uncorr), 1/s		0.351	0.352
kLa (corr), 1/s		0.216	0.217
kr, epsl, 1/s		0.014	0.014
KR(=kr,epsl.R.T/He)		0.002	0.002
KM(=kL.a.R.T/He)		0.037	0.037
K(=KR.KM/(KR+KM))		0.002	0.002
H2+CO Conversion, %	27.8	28.0	27.3
CO Conversion, %	26.1	29.2	28.4
STY, nm ³ /h/m ³		112.4	109.5
STY, nm ³ /h/kg Fe		3.68	3.58
Mass Transfer Res., %		5.92	5.90
CO Conv., gmole/kg Fe/h	107.5	100.59	98.03
-CH2 produced, g/kg Fe/h		881.84	859.44
g/nm ³ syngas		67.13	65.42

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 27
COMPARISON WITH LAPORTE SBCR RUN AF-R6.4-A

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	7.43	92.57	100
Density, g/cm ³	3.100	0.666	0.708
Volume % Solids	1.70	98.30	100.00
Viscosity, g/cm/s	-	0.0225	0.0256
Surface Tension, N/m	-	16.5	-
Part Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.91
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.42
Catalyst Weight, kg	74.9
Cat Loading, kg/m ³	52.6

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.0
Feed Rate, am ³ /hr	36.6
nm ³ /hr	271.3
SV, am ³ /hr/m ³	25.7
nm ³ /hr/m ³	190.5
nm ³ /h/kg Fe	6.73
Corr. factor for kLa	0.616
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.4-A		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	28.3	17.7	17.4
Ug, cm/sec		3.6	3.6
Gas hold-up, eps-g	0.157	0.120	0.120
kLa (uncorr), 1/s		0.346	0.346
kLa (corr), 1/s		0.213	0.213
kr, epsl, 1/s		0.008	0.008
KR(=kr, epsl, R.T./He)		0.001	0.001
KM(=kL.a. R.T./He)		0.037	0.037
K(=KR.KM/(KR+KM))		0.001	0.001
H2 + CO Conversion, %	28.6	19.4	19.0
CO Conversion, %	29.2	20.5	20.1
STY, nm ³ /h/m ³		36.9	36.2
STY, nm ³ /h/kg Fe		1.30	1.28
Mass Transfer Res., %		3.59	3.59
CO Conv., gmole/kg Fe/h	57.8	36.26	35.57
-CH2 produced, g/kg Fe/h		284.85	279.38
g/nm ³ syngas		42.30	41.49

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

TABLE 28
COMPARISON WITH LAPORTE SBCR RUN AF-R6.4-B

PROPERTIES OF SOLID AND LIQUID			
	Solid	Liquid	Slurry
Wt% Solids in Slurry	7.17	92.83	100
Density, g/cm ³	3.100	0.666	0.706
Volume % Solids	1.63	98.37	100.00
Viscosity, g/cm/s	-	0.0225	0.0255
Surface Tension, N/m	-	16.5	-
Part Size, microns	10.0	-	-

BUBBLE COLUMN DIMENSIONS	
	LaPorte
ID of Rx, cm	57.2
L of Rx, cm	609.6
Slurry Level, fraction	0.90
Rx X-section, m ²	0.26
Slurry Volume, m ³	1.41
Catalyst Weight, kg	71.2
Cat. Loading, kg/m ³	50.6

OPERATING CONDITIONS	
Rx Temperature, K	538
Rx Pressure, kPa	1480
Inlet Gas Vel., cm/s	4.0
Feed Rate, am ³ /hr	36.6
nm ³ /hr	271.3
SV, am ³ /hr/m ³	26.0
nm ³ /hr/m ³	192.8
nm ³ /h/kg Fe	7.08
Corr. factor for kLa	0.616
H2 Diffusivity, cm ² /s	0.00057

BUBBLE COLUMN MODEL CALCULATIONS			
RUN	AF-R6.4-B		
	Plant	MODEL 1	MODEL 2
H2 Conversion, %	28.3	16.8	16.6
Ug, cm/sec		3.6	3.6
Gas hold-up, eps-g	0.157	0.121	0.121
kLa (uncorr), 1/s		0.347	0.347
kLa (corr), 1/s		0.214	0.214
kr.εpsl, 1/s		0.008	0.008
KR(=kr.εpsl.R.T/He)		0.001	0.001
KM(=kL.a.R.T/He)		0.037	0.037
K(=KR.KM/(KR+KM))		0.001	0.001
H2 + CO Conversion, %	28.8	18.4	18.1
CO Conversion, %	29.2	19.5	19.2
STY, nm ³ /h/m ³		35.4	35.0
STY, nm ³ /h/kg Fe		1.30	1.28
Mass Transfer Res., %		3.45	3.45
CO Conv., gmole/kg Fe/h	58.1	36.18	35.73
-CH2 produced, g/kg Fe/h		284.21	280.69
g/nm ³ syngas		40.15	39.66

Model 1: Both gas and liquid in plug flow

Model 2: Gas in plug flow and liquid completely mixed

FIGURE A-1
SUMMARY DATA FOR UCI-"B" CATALYST - RUN 51

FIGURE A-2
SUMMARY DATA FOR UCI-"B" CATALYST - RUN 51

FIGURE A-3
SUMMARY DATA FOR UCI-"B" CATALYST - RUN 51

FIGURE A-4
SUMMARY DATA FOR UCI-"B" CATALYST - RUN 51

FIGURE A-5
SUMMARY DATA FOR UCI-"B" CATALYST - RUN 51

FIGURE A-6
SUMMARY DATA FOR UCI-"B" CATALYST - RUN 51

FIGURE A-7
SUMMARY DATA FOR UCI-"START-UP" CATALYST - RUN 53

FIGURE A-8
SUMMARY DATA FOR UCI-"START-UP" CATALYST - RUN 53

FIGURE A-9
SUMMARY DATA FOR UCI-"START-UP" CATALYST - RUN 53

FIGURE A-10
SUMMARY DATA FOR UCI-"START-UP" CATALYST - RUN 53

FIGURE A-11
SUMMARY DATA FOR UCI-"START-UP" CATALYST - RUN 53

FIGURE A-12
SUMMARY DATA FOR UCI-"START-UP" CATALYST - RUN 53

FIGURE A-13
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

FIGURE A-14
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

FIGURE A-15
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

FIGURE A-16
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

FIGURE A-17
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

FIGURE A-18
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

FIGURE A-19
SUMMARY DATA FOR UCI-"COMPOSITE" CATALYST - RUN 54

TABLE B-1
WEIGHT OF PRODUCTS COLLECTED IN TRAPS FOR RUN 51

(All weights are in grams)

Time-on-Stream, hours	Hot Trap		Ice Trap		Cryogenic Trap	
	Wax	Condensate	Hydrocarbon	Aqueous	1	2
12	4	13	22	13	5	-
24	3	13	26	17	2	2
48	5	24	43	45	7	2
2	340	34	41	60	10	7
96	6	27	48	65	9	5
120	6	29	48	61	10	4
144	8	27	54	62	10	5
168	181	33	55	63	16	9
192	8	32	59	60	7	6
216	68	34	52	56	12	10
240	8	36	62	56	15	9
264	52	37	60	54	10	6
288	55	35	60	49	16	15
312	57	38	58	48	19	13
336	142	135	56	45	22	6
360	30	42	64	46	22	13
TOTAL	532	499	808	800	192	112

TABLE B-2
WEIGHT OF PRODUCTS COLLECTED IN TRAPS FOR RUN 53

(All weights are in grams)

Time-on-Stream, hours	Hot Trap		Ice Trap		Cryogenic Trap	
	Wax	Condensate	Hydrocarbon	Aqueous	1	2
12	2	4	21	3	2	tr
24	2	9	25	8	9	15
48	2	23	51	22	19	8
72	2	30	48	23	13	7
96	27	172	33	28	8	5
120	24	115	25	33	13	3
144	28	113	37	20	15	12
168	36	62	39	25	11	7
192	122	22	53	34	98	11
216	111	128	58	38	13	10
240	135	56	47	32	10	9
264	87	32	27	8	6	0
288	119	19	21	9	7	6
312	103	28	19	12	8	5
336	137	8	25	13	13	5
360	137	18	26	11	11	7
384	125	5	29	12	13	5
TOTAL	1199	844	584	331	269	115

TABLE B-3
WEIGHT OF PRODUCTS COLLECTED IN TRAPS FOR RUN 54

(All weights are in grams)

Time-on-Stream, hours	Hot Trap		Ice Trap		Cryogenic Trap	
	Wax	Condensate	Hydrocarbon	Aqueous	1	2
12	3	22	6	8	2	2
24	-	28	15	7	5	8
48	6	29	31	5	17	7
72	50	24	30	19	12	5
96	66	29	19	23	16	3
120	169	26	19	25	22	6
144	91	47	25	20	17	4
168	149	37	23	19	12	67
192	122	36	25	18	12	7
216	94	109	30	27	10	5
240	20	152	44	28	9	7
264	80	101	44	39	5	5
288	221	41	50	63	23	9
312	203	37	57	53	18	6
336	-	-	58	49	17	10
360	147	31	57	44	25	8
384	160	22	44	31	16	6
408	10	15	32	14	12	2
432	38	10	29	13	10	3
456	131	17	23	12	12	4
490	39	10	26	11	7	5
504	84	8	42	6	-	-
TOTAL	1883	831	729	534	279	179

Figure C-1

PRODUCT DISTRIBUTION PLANT 700B, RUN 54, PERIOD 16

Figure C-2

PRODUCT DISTRIBUTION PLANT 700B, RUN 54, PERIOD 21

Table C-1

Period 16, Run 54
FISCHER TROPSCH - 1991

HYDROCARBON SAMPLES

SAMPLE 6827-70 Ice (0°C trap)

COMPOUND	AREA %
NC3	0.1
1-C2=O	1.506
1-C4=	0.2
NC4	0.2
C2OH	0.7
1-C3=O	0.7
1-C5=	0.1
NC5	1.506
1-C3OH	1.0
1-C4=O	0.2
1-C6=	0.5
NC6	0.2
1-C4OH	1.0
1-C5=O	0.6
1-C7=	1.4
NC7	0.9
1-C5OH	1.8
1-C6=O	0.4
1-C8=	3.0
NC8	1.4
1-C6OH	2.4
1-C9=	0.6
NC9	5.8
1-C7OH	2.3
1-C10=	2.7
NC10	2.4
1-C8OH	6.0
1-C11=	2.6
NC11	1.6
1-C9OH	4.6
1-C12=	2.1
NC12	0.9
1-C10OH	3.1
1-C13=	1.4
NC13	0.6
1-C14=	2.1
NC14	0.8
1-C15=	1.0
NC15	0.4
NC16	0.4
NC17	0.2
NC18	1.0

* Semi-quantitative due to interfering peaks

ANALYST SA
DATE 11-6-92

66.4
= each by 100

Table C-2

Period 16 (Run 54)
FISCHER TROPSCH - 1991

HYDROCARBON SAMPLES

SAMPLE 6827-70 Dry ice/acetone trap

COMPOUND	AREA %
NC3	0.4
1-C2=O	0.8
1-C4=	1.2
NC4	1.4
C2OH	1.4
1-C3=O	2.2
1-C5=	13.1
NC5	4.7
1-C3OH	0.7
1-C4=O	1.7
1-C6=	14.9
NC6	5.7
1-C4OH	0.1
1-C5=O	0.6
1-C7=	9.8
NC7	3.7
1-C5OH	0.9
1-C6=O	0.4
1-C8=	5.1
NC8	1.9
1-C6OH	0.3
1-C9=	1.9
NC9	0.7
1-C7OH	0.1
1-C10=	0.6
NC10	0.2
1-C8OH	-
1-C11=	0.2
NC11	0.1
1-C9OH	-
1-C12=	0.1
NC12	-
1-C10OH	-
1-C13=	0.1
NC13	-
1-C14=	-
NC14	-
1-C15=	-
NC15	-
NC16	-
NC17	-
NC18	-

* Semi-quantitative
due to interfering peaks

ANALYST SA

DATE 11-6-92

Period 16, Run 54
CHROMATOGRAPHIC LABORATORY
Des Plaines

mass - %

UOP-1440

To:

Period 21, Run 54

UDR#/Sample# P6827-71CLD

Description 6827-71 cold trap 11-39711 (0°C Trap)

FISCHER TROPSCH

Component
*****MASS% ★

C1-OH + C2-O	.4
C2-OH	1.4
N-C3-O	.2
C5=	.3
N-C5	.1
C3-OH	1.1
N-C4-O	.4
C6=	1
N-C6	.7
C4-OH	1.5
N-C5-O	1
C7=	2.2
N-C7	1
C5-OH	2
N-C6-O	1.5
C8=	4
N-C8	1.5
C6-OH	2.7
N-C7-O	1.1
C9=	5.4
N-C9	1.9
C7-OH	2.6
N-C8-O	1
C10=	5.4
N-C10	2
C8-OH	1.6
N-C9-O	.4
C11=	5
N-C11	1.8
C9-OH	1.4
C12=	4.3
N-C12	1.5
C10-OH	1.1
C13=	3.3
N-C13	1.3
C11-OH	.6
C14=	2.3
N-C14	1
C12-OH	.3
C15=	1.3
N-C15	.6
C16=	.6

Table C-4 (continued)

N-C16	.3
C17=	.2
N-C17	.1
C18=	.1
N-C18	.1
C19=	.1

Total 71.7001

P6827-71CLD
R55001

Injected at 11:16:47 ON NOV 30, 1992

Reference FI-14 p.200 Analyst P. Shah

* Semi-quantitative due to interfering peaks.

Period 21, Run 54

Table C-5

UDR Research, Gas Chromatography Laboratory
Des Plaines, Illinois

NOV 30, 1992

15:45:33

To:

UDR# / Sample# P6827-71 JCI

Description 6827-71 Ice Trap 11-39709 Dry Ice/Acetone Trap

FINCHER TROPSHIP

Component

MASS% *

C3= + N-C3

.1

C1-OH + C2-O

1.1

C4=

1.7

N-C4

.5

C2-OH

1.5

N-C4-O

1.9

C5=

9.2

N-C5

3

C3-OH

1.6

N-C4-O

1.6

C6=

13.5

N-C6

4.5

C4-OH

1.5

N-C5-O

1.4

C7=

10.1

N-C7

3.3

C5-OH

1.3

N-C6-O

.8

C8=

6

N-C8

1.9

C6-OH

.5

C9=

2.8

N-C9

1

C10=

1.4

N-C10

.5

C11=

.7

N-C11

.3

C12=

.4

N-C12

.2

C13=

.2

Total

74.5

P6827-71 ICE

R55002

Reference

Injected at 13:20:32 ON NOV 30, 1992

FI-14 P.200

Analyst

P. Shal

* semi quantitative due to interfering peaks

Table C-6

Period 21, Run 54

CHROMATOGRAPHIC LABORATORY

Des Plaines

GAS CHROMATOGRAPHY ANALYSIS

MASS - %

TO	S. Adami		(0°C)		(78°C)	
SAMPLE	6827-71 Aqueous		Cold Trap	Ice Trap		
* 1-C ₂ =O	-	4.2				
* Methanol	1.5	-				
Ethanol	5.8	8.5				
1-C ₃ =O	0.2	4.0				
Propanol	1.2	0.8				
1-C ₄ =O	0.1	0.4				
Butanol	3.5	0.2				
1-C ₅ =O	0.1	0.1				
Pentanol	0.1	-				
* 1-C ₂ =O and Methanol						
are not completely resolved						
at all times.						
REFERENCE						
ANALYST					DATE	
SA					11-20-92	

**DATE
FILMED**

2 / 16 / 94

END