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FINAL REPORT

TECHNOLOGY DEVELOPMENT FOR COBALT F-T CATALYSTS

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EXECUTIVE SUMMARY

Preliminary results on the effect of reaction temperature on the performance of Co catalysts during F-T synthesis obtained during the last quarter confirmed that Co catalysts were very sensitive to temperature and deactivated significantly at temperatures above 240°C both in the fixed bed and the slurry bubble column reactors. Following this preliminary investigation, a series of tests were carried out during this period in order to elucidate the nature of this deactivation process as well as determine possible means of preventing it. In order to elucidate the nature of this deactivation process, the catalysts which had undergone significant deactivation after high temperature (280°C) reaction in either the fixed bed reactor or the slurry bubble column reactor were regenerated and retested in the fixed bed reactor. In both cases the catalysts recovered completely their initial activity. In addition, reactions at very high H_2/CO ratios and high temperatures showed very little deactivation, suggesting that the deactivation of the Co catalysts during F-T synthesis at high temperatures was mainly due carbon formation via the Boudouard reaction. Due to the unreactive nature of this carbon, it could only be removed by calcination.

A second series of experiments was carried out to investigate the effect of certain promoters (Zr, La, Cr, and Re) as well as the effect of another support such as silica on the deactivation characteristics of Co catalysts during F-T synthesis at high temperature. The choice of these promoters was based on previous results from the slurry bubble column reactor, which indicated that catalysts with these promoters had undergone relatively lower deactivation under standard F-T synthesis runs. In addition, a series of new catalysts were formulated with a choice of promoters based on their intrinsic ability to enhance the hydrogenation reactions while slowing down the Boudouard reaction under the conditions used in F-T synthesis. The results suggest that the

deactivation process and rate for most of these catalysts are similar to those of the alumina-supported catalysts tested previously (Co.005 and Co.053), and that none of the promoters helps to slow down the rate of carbon formation at high temperatures above 240°C.. The only exception may be the use of Pd as promoter, although the amount added remains to be optimized since high concentrations result in low activity and high selectivity for methane. Further investigations of the effect of some of these promoters on preventing the deactivation of Co catalysts are still being carried out.

Several slurry bubble column reactor runs during this reporting period have also focussed on the effect of certain promoters on the general performance of the Co catalysts as well as their resistance to deactivation at high temperature. The results indicate that only the addition of Cr or Fe to cobalt catalysts can prevent their fast deactivation at high temperature. However, both promoters result in low overall activity catalysts with high selectivities for methane.

After the satisfactory performance tests carried out in the last quarter with the three 1 kg catalyst batches prepared by Calsicat, the 1000 hour aging test was carried out with one of these catalysts. The test was carried out under the standard conditions used in most of the previous runs, i.e., 450 psi and 240°C. As a result of this high temperature, the catalyst experienced excessive deactivation with the conversion dropping steadily over the first 600 hours from ca. 28% before leveling off for the remainder of the run at ca. 6.5%. A second shorter aging run (ca. 500 h) was carried out at lower temperature (212°C). Very little deactivation was observed under these conditions, confirming again the temperature sensitive nature of Co F-T catalysts.

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I. INTRODUCTION AND BACKGROUND

The goal of this project is the development of a commercially viable, cobalt-based Fischer-Tropsch (F-T) catalyst for use in a slurry bubble column reactor. Cobalt-based catalysts have long been known as being active for F-T synthesis. They typically possess greater activity than iron-based catalysts, historically the predominant catalyst being used commercially for the conversion of syngas based on coal, but possess two disadvantages that somewhat lessen its value: (1) cobalt tends to make more methane than iron does, and (2) cobalt is less versatile with low H_2/CO ratio syngas due to its lack of water-gas shift activity. Therefore, the major objectives of this work are (1) to develop a cobalt-based F-T catalyst with low (<5%) methane selectivity, (2) to develop a cobalt-based F-T catalyst with water-gas shift activity, and (3) to combine both these improvements into one catalyst. It will be demonstrated that these catalysts have the desired activity, selectivity, and life, and can be made reproducibly. Following this experimental work, a design and a cost estimate will be prepared for a plant to produce sufficient quantities of catalyst for scale-up studies.

II. PROJECT DESCRIPTION

The Cobalt Fischer-Tropsch Catalyst Project is divided into five tasks designed to systematically develop catalysts through thorough investigation of influences of various promoters, additives, and supports on minimizing methane selectivity and increasing water-gas-shift activity.

Cobalt has long been known to be an excellent catalyst for the F-T synthesis. Nevertheless, all currently operating F-T plants feeding coal produced syngas use iron catalysts, in spite of the fact that cobalt-based catalysts have higher activity. Two factors that lower cobalt's value as a F-T

catalyst are its poorer selectivity, that is, it produces more methane and its inability to be used with low H₂/CO ratio syngas because of its lack of water-gas shift activity. The broad objective of this proposal is to overcome these deficiencies.

In pursuing F-T catalyst development, there are several aspects that need to be considered. These are catalyst formulation, catalyst pretreatment, and catalyst performance. All of these aspects will be dealt with in this project.

In broad terms, the technical approach that will be used is outlined below.

- a. Conduct a thorough review of the literature on F-T synthesis, both the journal literature and the patent literature. In this review, identify approaches for improving methane selectivity of cobalt-based catalysts, identify additives that have WGS activity, identify catalyst formulation options, and define critical pretreatment parameters.
- b. Based on the above review, develop a list of catalyst formulations with potential for low methane selectivity and a list of catalyst formulations with potential for promoting the WGS reaction.
- c. Screen these catalysts in a small, fixed-bed reactor. If no catalyst meets the target specifications, go back to step b. Otherwise, run catalysts that meet discrimination criteria in a slurry bubble column reactor.
- d. Once catalysts with low methane selectivity and WGS activity have been identified, develop a catalyst combining both these functions and test as described above.
- e. Having found catalysts that meet the desired criteria for activity and selectivity, optimize the pretreatment conditions.
- f. Demonstrate catalyst reproducibility by having a commercial subcontractor prepare

multiple batches for testing.

- g. Demonstrate catalyst stability by running aging tests in a slurry bubble column reactor.
- h. Based on above results, prepare a design for a plant to produce demonstration scale batches of catalyst. Develop capital and operating costs of this plant.

The program to carry out the above outlined work will consist of five major tasks:

Task 1 -- Catalyst Development

Task 2 -- Catalyst Testing

Task 3 -- Catalyst Reproducibility Tests

Task 4 -- Catalyst Aging Tests

Task 5 -- Preliminary Design and Cost Estimate for a Demonstration Scale

Catalyst Production Facility

All aspects of the catalyst's role in F-T processing will be addressed, including catalyst preparation, pretreatment, and performance (activity, selectivity, and aging). In addition to gathering process data, the catalyst will be subjected to a number of analytical measurements at each stage to see how various treatments have affected the catalyst and its performance.

III. OBJECTIVES

The objective of this project is to investigate the influence of various promoters, additives, and supports on minimizing the methane selectivity and increasing the water-gas shift (WGS) activity of cobalt (Co) Fischer-Tropsch (F-T) catalysts. The ultimate goal of this investigation is to identify and demonstrate a catalyst preparation procedure that will be scaled up for the reproducible synthesis of commercial quantities of supported CO catalysts with desired activity, selectivity, and

lifetime for use in F-T synthesis in three-phase slurry bubble column reactors.

IV. SUMMARY OF WORK ACCOMPLISHED THIS QUARTER

Six new catalysts under subtask 1.2 and one under subtask 1.3 were formulated and prepared during this period in order to investigate the effect of certain promoters such Pd, Ru and Fe on the deactivation properties of Al_2O_3 -supported Co during F-T synthesis at high temperatures.

The characterization of all the catalysts in order to determine their physical properties (BET surface area, pore volume, pore size diameter, particle size distribution), as well as the cobalt reducibility, extent of reduction, and dispersion) was continued.

Fixed-bed reactor testing of the catalysts was continued. Four new catalysts were tested for their F-T synthesis performance. The main focus of the fixed bed testing during this period was the investigation of the deactivation behavior of Co catalysts during F-T synthesis at high temperatures, as well as the effect of certain promoters on this deactivation process. In addition, a couple of runs were carried out using regenerated catalysts used in either the fixed-bed reactor or the slurry bubble column reactor in order to elucidate the nature of the deactivation process as well as the extent of its reversibility.

During this reporting period, a total of 10 runs were performed in the slurry bubble column reactor. Out of these 10 runs, eight were miscellaneous runs carried to evaluate the effects of various promoters on the performance of Co catalysts in F-T synthesis under standard conditions. Some of these runs were also carried out at high temperature in order to evaluate the catalyst resistance to deactivation. Two runs were carried out for ca.1000 h for the first one and 500 h for the second one as part of the catalyst aging studies (Task 4) .

V. DETAILED DESCRIPTION OF TECHNICAL PROGRESS

A. TASK 1: CATALYST DEVELOPMENT

a. Technology Assessment (Subtask 1.1)

Except for regular updating of the literature with the most recent publications, there was no activity during this period to report in this subtask.

b. Catalyst Formulation (Subtasks 1.2, 1.3, 1.4)

An updated list of all the catalysts formulated so far within Subtask 1.2 (including those catalysts listed in previous quarterly reports) is given in Table 1 on page 17 with their compositions. The last column of Table 1 indicates whether the catalyst has already been prepared. Of the 89 catalysts listed in Table 1, five new Co catalysts and one Fe catalyst (highlighted in Table 1) were formulated and prepared in-house during this period. The detailed formulations of the new catalysts are given in Appendix A.

Co.066 (with 15% Co, 0.5% Ru, and 5% Fe on alumina), Co.067 (with 20% Co, 2% Pd on alumina), Co.068 (with 20% Co, 1% Pd on alumina), and Co.069 (with 20% Co, 2% Ru on alumina) were prepared this quarter in order to investigate the effect of certain promoters such Pd, Ru and Fe on the deactivation properties of Al_2O_3 -supported Co during F-T synthesis at higher temperatures than those usually used with Co catalysts. Carbon deposition resulting from enhanced Boudouard reaction at high temperature is believed to be the main cause of deactivation of the Co F-T catalysts. The choice of the promoters used in these formulations was based on their intrinsic ability to enhance the hydrogenation reactions while slowing down the Boudouard reaction under the conditions used in F-T synthesis. Two different loadings of Pd (1 and 2 wt%) were used, as well

as a higher Ru loading (2 wt%) than the one used so far with most of the previously formulated catalysts.

Co.070 (13% Co on alumina) was formulated with lower Co loading than used previously in order to complete the investigation on the effect of Co loading.

One alumina-supported iron catalyst (Fe.01) (30 wt% Fe and 1.5 wt% Cu) was also prepared for comparison purposes.

Under Subtask 1.3, one new FeCo-based catalyst (CoW.13) was prepared during this period. An updated list of all the catalysts formulated so far within Subtask 1.3 (including those catalysts listed in previous quarterly reports) is given in Table 2 on page 23 with their composition. The detailed formulation of the new catalyst is given in Appendix A. The catalyst was formulated with equal loadings of Co and Fe and was promoted with Ru. This catalyst was also formulated in order to investigate the effect of Fe on the catalysts deactivation by carbon deposition under high temperature reaction conditions.

c. Catalyst Characterization (Subtask 1.6)

Physical Properties

Table 3 on page 24 gives an update on the physical property measurements carried out so far. Nitrogen physisorption at 77 K was used to obtain surface area, pore volume and pore diameter of the calcined catalysts. Average particle size of the catalysts was determined using a Microtrac particle size analyzer.

Static Hydrogen Chemisorption

An updated summary of the properties of the Co catalysts as determined by H₂ chemisorption is given in Table 4 on page 27.

Temperature Programmed Reduction (TPR)

TPR experiments were carried out in an automated Altamira Instruments AMI-1 system. The procedure for these measurements was described in a previous quarterly report. All the TPR results obtained so far are summarized in Table 4 on page 27.

B. TASK 2: CATALYST TESTING

a. Subtask 2.1 - Fixed Bed Reaction Studies:

The reaction conditions and procedure were described in previous quarterly reports. Four (4) new catalysts (Co.064, Co.066-Co.068)) were tested for the first time during this reporting period. Catalysts Co.025 (run #2-2a), Co.053 (run #12-14), Co.055 (run #8-8a) and catalyst CoW.05 (run #3-3a) were also retested in order to investigate the effect of reaction temperature on the deactivation of Co catalysts during F-T synthesis and determine the cause of such deactivation. For this purpose, the reaction was initiated at 220°C and allowed to proceed for ca. 20h to reach steady-state. After dilution of the reactant stream with Ar ($H_2/CO/Ar = 2/1/1$), the temperature was increased to 280°C over a period of 2.5h and CO hydrogenation was continued at 280°C for another 20-40h. The performances of all these catalysts (highlighted in Table 5) at steady state are compared in Table 5 on page 31 with those reported in the previous quarterly report. All the pertinent data (CO conversion, rates, product distributions, chain growth probabilities, Anderson-Schulz-Flory distributions, time-on-stream activity and Arrhenius plots when available) obtained with each run for each catalyst is given in Appendix B.

Co.064, a Ru- and Zr-promoted Co/Al_2O_3 catalyst was tested as part of the study of the effect of promoters on alumina-supported F-T Co catalysts. Previous results with a similar catalyst

without the Ru promoter (Co.034) showed that ZrO_2 promotion alone enhanced significantly the activity of Co catalysts for F-T synthesis. It is clear from the results obtained for Co.064 that Ru promotion results in another significant increase in activity from that obtained with Co.034.

As reported previously, most of the highly active catalysts deactivated promptly as soon as they were subjected to relatively high temperatures resulting from excessive and uncontrolled release of the heat of reaction. The preliminary investigation of the effect of reaction temperature on the performance of Co catalysts during F-T synthesis described in the previous quarterly report indicated that the Co catalysts tested (Co.005 and Co.053) were very sensitive to temperature and deactivated rather quickly at temperatures above 240°C . In order to elucidate the nature of this deactivation process, the catalysts which had undergone significant deactivation after high temperature (280°C) reaction in either the fixed bed reactor or the slurry bubble column reactor were regenerated and retested in the fixed bed reactor. In one experiment (Co.053, run #13) the catalyst was regenerated *in-situ* by calcination in flowing air at 300°C for 10h, re-reduced in flowing H_2 at 350°C for 10h and the CO hydrogenation carried out again at 220°C to check for the reversibility of the deactivation process. In another experiment (Co.053, run #14), a catalyst which had been run for several days in the slurry bubble column reactor was again regenerated in flowing air 300°C for 10h and re-reduced in flowing H_2 at 350°C for 10h before carrying out CO hydrogenation at 220°C . In both cases the catalysts recovered completely their initial activity. In addition, reactions at very high H_2/CO ratios and high temperatures showed very little deactivation. All these results suggest that the deactivation of the Co catalysts during F-T synthesis at high temperatures above 240°C in both the fixed-bed and the slurry bubble column reactors was mainly the result of carbon deposition on the catalyst surface.

A second series of experiments was carried out to investigate the effect of certain promoters (Zr, La, Cr, and Re) as well as the effect of another support such as silica on the deactivation characteristics of Co catalysts during F-T synthesis. Co.025, Co.055, and CoW.05 were used for this purpose. In addition, preliminary results were also obtained with the newly formulated catalysts containing Pd or Fe (Co.066-Co.068). All these catalysts were tested as indicated, first at 220°C than at 280°C, while monitoring their deactivation. The results suggest that the deactivation process and rate are similar to those of the alumina-supported catalysts tested previously (Co.005 and Co.053), and that none of the promoters helps to slow down the rate of carbon formation at high temperatures above 240°C. In addition, promotion with high loadings of Fe or Pd resulted in catalysts with relatively lower activity and higher methane selectivity. The only exception was Co.068 with 1% Pd which had adequate activity and selectivity as well as lower deactivation rate at high temperature. Further investigation of the deactivation characteristics of these Co catalysts using olefin hydrogenation and Boudouard reactions may help in the formulation of new Co catalysts which are more resistant to deactivation at high temperature.

b. Subtask 2.2 - Slurry Bubble Column Reactor Testing

1. Run Chronology

During this reporting period a total of 10 runs were performed in the SBCR's, Runs M3-40 through 47, and M4-33 and 35. A chronology of the experimental runs performed in the two slurry bubble column reactors - M3 and M4 - is given in Appendix C. All comparisons of CO conversion and CH₄ selectivities discussed in this chronology were obtained from results obtained at the initial startup conditions -- 240°C temperature, 450 psi pressure, and 2/1 H₂/CO feed gas ratio.

A complete summary of all runs made in the M3-SBCR is given in Table I in Appendix D.

Four tables of data were prepared in order to compare catalyst activities for Runs 2 to 47 in M3-SBCR at the same run conditions (see Tables II, III, IV, and V in Appendix D).

A complete summary of all runs made in the M4-SBCR is given in Table VI, Appendix D. Four tables were prepared to compare catalyst activities for Runs 3 to 33 in M4-SBCR at the same run conditions (see Tables VII, VIII, IX, and X in Appendix D). A summary of all runs using catalysts made by Calsicat are given in Table XI, Appendix D.

2. Discussion of Results

(a) Miscellaneous Runs Made to Evaluate the Effects of Various Promoters

One run was made with a catalyst containing 20% Co and 8.5% La_2O_3 on alumina support (see Run 40 in M3-SBCR in Table 6). The CO conversion at startup conditions was only 8.7% which is considerably lower than the 28% CO conversion obtained with Catalyst No. Co.058 (Run 38 in M3) that contained 1.0% La_2O_3 . Too much La_2O_3 reduced the catalyst activity significantly.

One run was made with a catalyst containing 30% Co with 0.5% Ru and 1.5% K on alumina support (see Run 41 in M3-SBCR in Table 6). The CO conversion was only 6.6% which is considerably lower than that obtained with similar catalysts containing 0.1, 0.3, and 0.5% K. Apparently the amount of K added was too high and reduced catalyst activity significantly.

Another run was made with a catalyst containing 20% Co with 0.5% Ru plus 0.3% K and 8.5% Zr (see Run 42 in M3-SBCR in Table 6). The CO conversion at startup conditions was 27.6%, almost identical to that obtained with Catalyst No. Co.047 which contained no Zr. The total hydrocarbon product rates and CH_4 selectivities were also identical. The addition of Zr to alumina supported catalysts has little or no effect on the catalyst activity.

A fourth run was made with a catalyst containing 13% Co with no promoters on alumina

support. The CO conversion at startup conditions was 22.8% with a CH₄ selectivity of 10.9% (see Run 47 in M3-SBCR in Table 6). The CO conversion with a 20% Co catalyst with no promoters was 27.1% and 31.4% with a catalyst containing 30% Co (see Runs M3-15 and M3-34 in Table 6). The catalyst activity does not appear to be directly proportional to the Co concentration.

One run was made with a combination cobalt/water-gas-shift catalyst containing 20% Co, 5.0% Cu and 4.0% Cr on alumina support (see Run 46 in M3-SBCR in Table 6). The CO conversion at startup conditions was quite low, 4.0%, with a CH₄ selectivity of 10.9%. The CO conversion increased to 14.0% at 280°C and 19.4% at 300°C. The CH₄ selectivity increased to 44.2% and 54.4%, respectively. This catalyst is unsatisfactory because of its low activity and high selectivity to lower carbon numbers.

The following conclusions can be made on the effects of adding various promoters based on the preceding experiments:

- The addition of a large amount of La₂O₃ on an alumina supported catalyst considerably reduced the catalyst activity.
- The addition of a high amount of K (1.5 wt%) greatly reduced the catalyst activity.
- The addition of Zr to alumina supported catalysts has little or no effect on catalyst activity.
- The catalyst activity is not directly proportional to the amount of Co added.

(b) Catalysts Containing Cobalt and Iron

One run was made with a catalyst (CoW.12) containing 10% Co, 10% Fe, and 0.5% Ru on silica support (see Run 43 in M3-SBCR in Table 6). The initial CO conversion was only 6.1% with a CH₄ selectivity of 20.3% and CO₂ selectivity of 7.3%. The CO conversion increased to 24.5% at

280°C with a CH₄ selectivity of 25.6% and CO₂ selectivity of 11%. The combination Co plus Fe catalyst gave low CO conversion levels plus high CH₄ and CO₂ selectivities on the silica support.

A second run was made with a catalyst (CoW.11) containing 10% Co, 10% Fe, with 0.5% Ru and 0.5% K on an alumina support (see Run 44 in M3-SBCR in Table 6). The CO conversion at startup conditions was lower, 4.7%, as expected. CO conversion increased to 25.1% at 280°C while the CH₄ selectivity increased to 25.6%. The addition of K reduced the CO conversion slightly, but also reduced the CH₄ selectivity significantly.

A third run was made with a catalyst (Fe.01) containing 30% Fe plus 1.5% Cu on a silica support (see Run 45 in M3-SBCR in Table 6). This was the only iron catalyst without Co that has been tested. The initial CO conversion was very low, 3.4%, while the CH₄ selectivity was too low to detect by our GC. The CO conversion increased to 14.5% at 280°C with a CH₄ selectivity of 23.3%, and a CO conversion of 19.0% and CH₄ selectivity of 26.7% at 300°C reaction temperature. In general, the iron catalyst had much lower activity and produced more CH₄ and CO₂ than cobalt catalysts in the slurry bubble catalytic reactors.

(c) Investigation of the Effect of Temperature on Catalyst Deactivation

Several of the catalysts from the SBCR runs were submitted for total carbon analysis (see Table 7). All catalysts were run at 240°C, except Run 3029 which was run at 260°C and Run 3030 had reached 320°C reaction temperature. In general, most recovered catalysts contained 5 to 9% carbon. The high temperature run, Run 3030, contained 13.5% carbon. One silica supported catalyst, containing 8.5% Zr, contained only 0.52% carbon. It has been demonstrated in fixed bed reactor studies that Co catalysts are very sensitive to temperature. They deactivate very fast at temperatures at or above 240°C. A test was made in the fixed bed reactor where one of these

catalysts was recalcined and H_2 reduced, and yielded catalyst activity similar to the fresh catalyst charge.

3. Catalyst Recovery Analyses

The catalysts charged for all runs, except for Runs 4, 20, and 29 in M4, have been recovered and the particle size distributions have been measured. The charge and recovered weights of all catalysts are given in Table 8. The charge weights are in the H_2 reduced state while the recovered weights are in the oxidized state. Taking this into account, catalyst recoveries are quite good (greater than 90%). The mean volumetric diameters of both the charged and recovered catalysts with the calculated percent reductions in particle size are also given in Table 8. The particle size at the lower 10% pass-through point of the sample for both the charged and recovered catalysts are also given in Table 8.

A comparison of the mean volume diameters of the total feed and recovered samples shows that most of the alumina supported catalysts exhibited the least amount of particle size attrition (5 to 10%) during the reaction. The silica supported catalysts showed a 10 to 20% particle size reduction while a titanium supported catalyst had the highest reduction, 18.2% (see Run 8 in the M4-SBCR in Table 8).

Eleven catalysts prepared by Calsicat have been tested in the SBCR and the particle size reduction was very low, 0.5% for CAL.08 and 1.6% for CAL.05. All these catalysts were prepared on a Vista-B gamma-alumina catalyst support which has shown good resistance to attrition in the SBCR's.

If you compare the particle size of each sample of the 10% pass-through point, the increase in the amount of fines found in the recovered catalysts, as indicated by the lower particle size at the

10% point, is nearly proportional to the reduction in particle size obtained by comparing the mean volume diameters of the charge vs. recovered catalysts (see Table 8). Since the particle size of the charge catalyst was determined on the catalyst after hydrogen reduction and air oxidation, we know that attrition occurred only during the SBCR reaction.

B. TASK 4: CATALYST AGING STUDIES

a. First Aging Test at 240°C

Run No. 33 in M4-SBCR was started on March 6th with a charge of 15.9 gm of Calsicat Catalyst No. CAL.13 and shut down on April 20th after 1069 hours on stream (see Table 9). The initial CO conversion at startup conditions was 28.1% with a CH₄ selectivity of 6.4% and a THC production rate of 1.28 gm C₁+/g cat/hr. The CO conversion dropped steadily over the first 600 hours, and then leveled off for the remainder of the run, see Figure 1. The production rate loss paralleled the CO conversion loss (see Figure 2), but the CH₄ selectivity rose from 6.5 to 9.5% over the run duration (see Figure 3). The average catalyst deactivation rate based on the total CO converted over the entire run was 30.1 gm CO/Kg catalyst/hr.

b. Second Aging Test at 212°C

Run No. 35 in M4-SBCR was started on June 14th with a charge of 25.0 gm of Calsicat Catalyst No. CAL.13 to attempt a catalyst aging run at lower reaction temperatures (see Table 10). The CO conversion was a little too high at 220°C (17.2%), so the reaction temperature was held at 212°C where the initial CO conversion averaged 8.9%. After 240 hours on-stream the CO conversion leveled out at 7.4% for the remainder of the run, a total of 524 hours on-stream (see Figure 4). The production rate started at 0.26 gm C₁+/gm cat/hr at initial startup, but leveled out at 0.22 g/g/hr at

225 hours for the remainder of the run (see Figure 5). The CH₄ selectivity at 212°C was too low to measure, so it was reported as 0% (see Figure 6). The average rate of deactivation of the catalyst was about 5.96 gm CO/Kg cat/hr per Kg CO converted. The deactivation rate at 240°C was 30.1 gm CO/Kg cat/hr per Kg CO converted; thereby demonstrating that catalyst deactivation is mainly dependent on temperature rather than on total syngas consumed.

VI. PLANS FOR THE NEXT REPORTING PERIOD

Several tasks are planned for the next reporting period:

- (a) The fixed-bed reactor testing of new catalysts will be completed.
- (b) The systematic characterization of all the catalysts will be completed using the following techniques:
 - Selective hydrogen chemisorption on the reduced catalysts at 100°C;
 - X-ray diffraction before reduction, after reduction, and after slurry bubble column reaction;
 - Temperature programmed reduction (TPR);
- (c) The investigation of the effect of temperature on catalyst deactivation will be completed.
- (d) An investigation of the effect of certain promoters on the Boudouard reaction and on olefin hydrogenation reactions will be carried out
- (e) Additional runs will be made in the SBCR's to test the newly formulated catalysts.
- (f) An additional aging run will be made on catalyst obtained from Calsicat.
- (g) An iron catalyst supplied by DOE will be tested in the SBCR after an optimization of the conditions simulating the previous LaPorte run with the same catalyst..

(e) The writing of the final report will be started.

VII. ASSESSMENT OF PROSPECTS FOR FUTURE PROGRESS

The technical approach which has been proposed remains the same and all the tasks are proceeding within schedule.

Table 1. List of Co-based FT Catalysts Formulated

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.001	20%	1% Re	1% La ₂ O ₃ , 0.13% K	γ-alumina	U.S. Pat. 4,880,763	P
Co.002	20%	0.43% Ru	1% La ₂ O ₃	γ-alumina	U.S. Pat. 4,413,064	P
Co.003	20%	0.5% Ru	1% La ₂ O ₃	γ-alumina	U.S. Pat. 4,413,064	P
Co.004	20%	0.43% Ru	1% La ₂ O ₃	γ-alumina	Reproduce Co.002	P
Co.005	20%	0.00	0.00	γ-alumina	Base Catalyst	P
Co.005A	20%	0.4% Ru	0.00	γ-alumina	Ru added to calcined Co.005 by IW impreg.	P
Co.006	12%	0.75% Re	0.00	Titania	U.S. Pat. 4,794,009	P
Co.007	20%	0.00	0.00	Titania	Base Catalyst	P
Co.008	20%	0.00	0.00	Silica	UK Pat. Appl. GB 2 125 062 A (Kneaded with excess liquid)	P
Co.009	20%	0.5% Ru	0.00	γ-alumina	Ru-Promoted Catalyst (use Ru Chloride, single-step aqueous IW)	P
Co.010	20%	0.00	0.00	γ-alumina	Base Catalyst (non-calcined)	P
Co.010A	20%	0.4% Ru	0.00	γ-alumina	Ru added to dried Co.010 by IW impreg.	P
Co.011	20%	0.00	0.00	Silica	UK Pat. Appl. GB 2 125 062 A (Kneaded)	P
Co.012	20%	0.00	0.00	Silica	Base Catalyst (Inc. Wetness)	P
Co.013	20%	0.00	0.00	Titania	Base Catalyst like Co.007, but all aqueous	P
Co.014	12%	0.5% Ru	0.00	Titania	Ru-Promoted Catalyst (aqueous IW co- impregnation)	P
Co.015	20%	0.43% Ru	1% La ₂ O ₃	γ-Alumina	Similar to Co.002, but all aqueous	P

Table 1. List of Co-based FT Catalysts Formulated (contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.016	20%	0.43% Ru	1% La ₂ O ₃	γ -Alumina	Similar to Co.015, but calcined after Co impregnation	P
Co.017	20%	0.5% Ru	1% La ₂ O ₃	γ -Alumina	Similar to Co.003, but all aqueous	P
Co.018	20%	0.5% Ru	0.00	γ -Alumina	Ru-Promoted Catalyst (single-step, aqueous IW)	P
Co.019	20%	0.5% Ru	0.00	Silica	Ru-Promoted Catalyst (single-step, aqueous IW)	P
Co.020	0.00	0.5% Ru	0.00	γ -Alumina	Ru Base Catalyst	P
Co.020A	20%	0.4% Ru	0.00	γ -Alumina	Co added to dried Co.020 by IW impreg.	P
Co.020B	20%	0.4% Ru	0.00	γ -Alumina	Co added to reduced Co.020 by IW impreg.	P
Co.020C	20%	0.4% Ru	0.00	γ -Alumina	Co added to calcined Co.020 by IW impreg.	P
Co.021	20%	0.00	0.7% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (single-step, aqueous kneaded)	P
Co.022	20%	0.00	0.7% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (aqueous, multiple-steps, kneaded Co pre-impregnation, IW Zr)	P
Co.023	20%	0.00	1.4% Zr	Silica	U.K. Pat. Appl. GB 2 125 062 A (aqueous, multiple-steps, kneaded Co pre-impregnation, IW Zr)	P
Co.024	20%	0.00	8.5% Zr	Silica	Eur. Pat. Appl. 0 167 215 A2 (non-aqueous, IW, multiple-steps, Zr pre-impregnation)	P
Co.025	20%	0.00	8.5% Zr	Silica	Similar to Co.024 but aqueous Zr pre-impregnation	P
Co.026	20%	0.00	0.00	Silica (Davison Grade 59)	Similar to Co.012 but different grade silica	P

Table 1. List of Co-based FT Catalysts Formulated (contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.027	20%	0.5% Ru	0.00	Silica (Davison Grade 59)	Similar to Co.019 but different grade silica	P
Co.028	20%	0.5% Ru	0.5% K	γ -alumina	Ru- and K-Promoted Catalyst (single-step IW)	P
Co.029	30%	0.5% Ru	0.5% K	γ -alumina	Similar to Co.028 but 30% Co	P
Co.030	20%	0.00	0.1% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.031	20%	0.00	1.4% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.032	20%	0.00	8.5% Zr	γ -alumina	Zr-Promoted Catalyst (single-step aqueous IW)	P
Co.033	20%	0.00	8.5% Zr	γ -alumina	Multiple-steps, aqueous IW, Co pre-impregnation	P
Co.034	20%	0.00	8.5% Zr	γ -alumina	Multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.035	20%	0.00	8.5% Zr	Silica	Zr-Promoted Catalyst (single-step aqueous, kneaded)	P
Co.036	20%	0.00	8.5% Zr	Silica	Multiple-steps, aq. Co pre-impreg. by kneading, aqueous IW Zr impreg.	P
Co.037	12%	0.00	0.00	Titania	Similar to Co.013, but TiO ₂ , mainly anatase	P
Co.038	12%	0.5% Ru	0.00	Titania	Similar to Co.014, but TiO ₂ , mainly anatase	P
Co.039	12%	0.00	0.00	Titania	Similar to Co.007, but only 12% Co	P
Co.040	12%	0.00	0.00	Titania	Similar to Co.013, but only 12% Co	P
Co.041	20%	0.5% Ru	8.5% Zr	Silica	Similar to Co.025, but Ru-promoted	P
Co.042	0.00	0.00	8.5% Zr	Silica	Blank Zr-promoted SiO ₂	P

Table 1. List of Co-based FT Catalysts Formulated (contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.043	20%	0.5% Ru	8.5% Zr 0.5% K	Silica	Similar to Co.041, but K-promoted	P
Co.044	20%	0.00	15% Zr	Silica	Similar to Co.025, but 15% Zr	P
Co.045	20%	0.00	4% Zr	Silica	Similar to Co.025, but 4% Zr	P
Co.046	12%	0.75% Re	4% SiO ₂	Titania	Similar to Co.006, but SiO ₂ -promoted	-
Co.047	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.028, but 0.3% K	P
Co.048	20%	0.5% Ru	8.5% Zr 0.3% K	Silica	Similar to Co.043, but 0.3% K	P
Co.049	20%	0.5% Ru	0.1% K	γ -alumina	Similar to Co.047, but 0.1% K	P
Co.050	20%	0.5% Ru	8.5% Zr 0.1% K	Silica	Similar to Co.048, but 0.1% K	P
Co.051	0.00	0.5% Ru	0.00	Titania (R)		P
Co.052	0.00	0.5% Ru	0.00	Titania (A)		P
Co.053	20%	0.5% Ru	0.00	γ -alumina	Similar to Co.018 (New Batch)	P
Co.054	20%	0.00	8.5% Zr 0.3% K	Silica	Similar to Co.043, but without Ru	P
Co.055	20%	1% Re	1% La ₂ O ₃	γ -alumina	Similar to Co.001, but without K	P
Co.056	20%	0.00	8.5% La ₂ O ₃	Silica	Similar to Co.025, but La instead of Zr	P
Co.057	20%	1% Re	1% La ₂ O ₃	Silica	Similar to Co.055, but with SiO ₂ support	P
Co.058	20%	0.00	1% La ₂ O ₃	γ -alumina	Similar to Co.055, but without Re (one-step impreg.)	P
Co.059	20%	0.00	1% La ₂ O ₃	γ -alumina	Similar to Co.015, but without Re (two-step impreg.)	P
Co.060	30%	0.00	0.00	γ -alumina	Similar to Co.005, but with 30% Co	P
Co.061	30%	0.5% Ru	0.00	γ -alumina	Similar to Co.053, but with 30% Co	P
Co.062	30%	0.5% Ru	1.5% K	γ -alumina	Similar to Co.029, but with 1.5% K	P

Table 1. List of Co-based FT Catalysts Formulated (contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
Co.063	20%	0.00	8.5% La	γ -alumina	Multiple-steps, aqueous IW, La pre-impregnation	P
Co.064	20%	0.5% Ru	8.5% Zr	γ -alumina	Multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.065	20%	0.5% Ru	8.5% Zr 0.3% K	γ -alumina	Multiple-steps, aqueous IW, Zr pre-impregnation	P
Co.066	15%	0.5% Ru, 5.0% Fe	0.00	γ -alumina	Ru- and Fe-Promoted Catalyst (single-step, aqueous IW)	P
Co.067	20%	2.0% Pd	0.00	γ -alumina	Pd-Promoted Catalyst (single-step, aqueous IW)	P
Co.068	20%	1.0% Pd	0.00	γ -alumina	Similar to Co.067, but with 1% Pd	P
Co.069	20%	2.0% Ru	0.00	γ -alumina	Similar to Co.053, but with 2% Ru	P
Co.070	13%	0	0.00	γ -alumina	Similar to Co.005, but with 13% Co	P
CAL.01 (97E-13E)	20%	0.5% Ru	0.00	γ -alumina	Similar to Co.018 (Calsicat Prep.)	P
CAL.02 (97E-16B)	20%	0.5% Ru	0.00	γ -alumina	Similar to CAL.01 (New Batch)	P
CAL.03 (97E-13F)	20%	0.5% Ru	0.00	γ -alumina	Multiple-step impreg., Similar to CAL.02	P
CAL.04 (97E-50C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Stand. Calc. in Air	P
CAL.05 (97E-50D)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Stand. Calc. in N ₂	P
CAL.06 (97E-51A)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Red. and Pas. in Air	P
CAL.07 (97E-51B)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Red. and Protected in Paraffin (51.3% Cat. Conc.)	P
CAL.08 (97E-51C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to Co.047 Calc., Red. and Protected in Paraffin (54.4% Cat. Conc.)	P

Table 1. List of Co-based FT Catalysts Formulated (contd.)

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
CAL.09 (97E-69C)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05, Reduced and Protected in Soya (51.7% Cat. Conc.)	P
CAL.10 (97E-79A)	20%	0.5% Ru	0.3% K	γ -alumina (Condea)	Similar to CAL.05, but on Condea Al_2O_3	P
CAL.11 (29F-07B)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05	P
CAL.12 (29F-05D)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05	P
CAL.13 (29F-07E)	20%	0.5% Ru	0.3% K	γ -alumina	Similar to CAL.05	P
Fe.01	0%	30%Fe	1.5%Cu	Silica		P

Table 2. List of Water-Gas Shift Catalysts and F-T Catalysts with WGS Function

CAT. NO.	wt% Co	wt% M	wt% Prom.	Support	Basis	Prepared
WGS.01	0	5.0% Cu	0	γ -alumina	single-step, aqu. IW	P
WGS.02	0	5.0% Cu	10% Zn	γ -alumina	single-step, aqu. IW	P
WGS.03	0	5.0% Cu	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.04	0	0	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.05	0	0	4.0% Mn	γ -alumina	single-step, aqu. IW	P
WGS.06	0	5.0% Cu	4.0% Mn	γ -alumina	single-step, aqu. IW	P
WGS.07	0	4.0% Fe	0	γ -alumina	single-step, aqu. IW	P
WGS.08	0	4.0% Fe	4.0% Cr	γ -alumina	single-step, aqu. IW	P
WGS.09	0	5.0% Cu	4.0% Cr	γ -alumina	Similar to WGS.03	P
CoW.01	20%	5.0% Cu	10% Zn	γ -alumina	multiple-steps, aqu. IW, Cu,Zn pre-impr.	P
CoW.02	20%	5.0% Cu	4.0% Cr	γ -alumina	multiple-steps, aqu. IW, Cu,Cr pre-impr.	P
CoW.03	10%	5.0% Cu	4.0% Cr	γ -alumina	similar to CoW.02 (10% Co only)	P
CoW.04	10%	10% Cu	8.0% Cr	γ -alumina	similar to CoW.03; 10% Cu and 8% Cr	P
CoW.05	20%	5.0% Cu	4.0% Cr	γ -alumina	similar to CoW.02 with support calcined at 750°C	P
CoW.06	20%	5.0% Cu	4.0% Cr	Silica	multiple-steps, aqu. IW, Cu,Cr pre-impr.	P
CoW.07	20%	5.0% Cu	4.0% Cr	Silica	similar to CoW.06, but with support calcined at 750°C	P
CoW.08	30%	5.0% Cu	4.0% Cr	γ -alumina	Similar to CoW.05, but with 30% Co	P
CoW.09	20%	10.0% Cu	8.0% Cr	Silica	similar to CoW.06, but with 10% Cu and 8% Cr	P
CoW.10	10% Co, 10% Fe	0.5% Ru	0	γ -alumina	Single Step, IW	P
CoW.11	10% Co, 10% Fe	0.5% Ru	0.5% K	γ -alumina	Single Step, IW	P
CoW.12	10% Co, 10% Fe	0.5% Ru	0	Silica	Single Step, IW	P
CoW.13	10% Co, 10% Fe	0.5% Ru	0	γ -alumina	Similar to CoW.10 (2nd batch)	P

Table 3. Summary of Physical Properties

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
Vista-B Al ₂ O ₃	(0-400 mesh)	299	1.69	269	24
Vista-B Al ₂ O ₃	Calcined 500°C	240	0.49	82	
Vista-B Al ₂ O ₃	Calcined 600°C	206	0.49	95	
Vista-B Al ₂ O ₃	Calcined 600°C	174	0.47	109	
Condea Al ₂ O ₃	(as received)	219	0.53	97	77
Davison SiO ₂	(0-400 mesh)	219	0.51	89	121
Degussa P25 TiO ₂	(as received)	47	0.40	335	6
Degussa P25 TiO ₂	Dried 60°C, Calc. 350°C/16hrs	46	0.48	419	51
Degussa P25 TiO ₂	Dried 60°C, Calc. 650°C/16hrs	12	0.17	573	212
Co.001	20Co/1Re/ 1La ₂ O ₃ /0.13K/A	191	0.31	66	42 40
Co.002	20Co/0.43Ru/ 1La ₂ O ₃ /A	149	0.33	89	74
Co.003	20Co/0.5Ru/ 1La ₂ O ₃ /A	122	0.26	87	77
Co.004	20Co/0.43Ru/ 1La ₂ O ₃ /A				78
Co.005	20Co/A	173	0.34	81	65 86
Co.006	12Co/0.75Re/T	16	-	-	121
Co.007	20Co/T	11	0.10	372	
Co.008	20Co/S	181	1.06	234	
Co.009	20Co/0.5/A				
Co.010	20Co/A				
Co.011	20Co/S	211	1.07	203	107
Co.012	20Co/S	211	-	-	105
Co.013	20Co/T				
Co.014	12Co/0.5Ru/T	15	0.12	328	111

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
Co.015	20Co/0.43Ru/ 1La ₂ O ₃ /A	141	-	-	67
Co.016	20Co/0.43Ru/ 1La ₂ O ₃ /A	116	-	-	79
Co.017	20Co/0.5Ru/ 1La ₂ O ₃ /A	123	-	-	73
Co.018	20Co/0.5Ru/A	158	-	-	69
Co.019	20Co/0.5Ru/S				110
Co.021	20Co/0.7Zr/S	213	1.12	210	74
Co.023	20Co/1.4Zr/S	213	-	-	
Co.024	20Co/8.5Zr/S	215	1.08	202	
Co.025	20Co/8.5Zr/S	208	0.97	187	87
Co.026	20Co/S(59)	184	-	-	
Co.027	20Co/S(59)	189	-	-	
Co.028	20Co/0.5Ru/0.5K/A	161	0.33	82	80
Co.029	30Co/0.5Ru/0.5K/A	140	-	-	76
Co.031	20Co/1.4Zr/S				75
Co.032	20Co/8.5Zr/A	155	0.30	77	
Co.034	20Co/8.5Zr/A	150	0.31	83	
Co.035	20Co/8.5Zr/S	207	1.21	233	89
Co.036	20Co/8.5Zr/S	209	-	-	
Co.037	12Co/T(A)	38	-	-	
Co.039	12Co/T(R)	13	-	-	
Co.040	12Co/T				130
Co.041	20Co/0.5Ru/8.5Zr/S	214	-	-	-
Co.044	20Co/15Zr/S				92
Co.047	20Co/0.5Ru/0.3K/A	162	0.31	78	83
Co.048	20Co/0.5Ru/0.3K/ 8.5Zr/S				82

CATALYST	Composition	BET Surface Area (m ² /g)	Pore Volume (cc/g)	Average Pore Dia. (Å)	Average Part. Size (µm)
Co.049	20Co/0.5Ru/0.3K/A				81
Co.053	20Co/0.5Ru/A				75
Co.054	20Co/0.3K/8.5Zr/S				101
Co.055	20Co/1Re/ 1La ₂ O ₃ /A				86
Co.056	20Co/8.5La ₂ O ₃ /S				100
CAL.01	20Co/0.5Ru/A	178	0.34	76	
CAL.02	20Co/0.5Ru/A	158	-	-	74
CAL.03	20Co/0.5Ru/A	158	-	-	
CAL.04	20Co/0.5Ru/0.3K/A	151			72
CAL.05	20Co/0.5Ru/0.3K/A	163			73
CAL.06	20Co/0.5Ru/0.3K/A	162			72
CAL.07	20Co/0.5Ru/0.3K/A	-			
CAL.08	20Co/0.5Ru/0.3K/A	-			63
CAL.09	20Co/0.5Ru/0.3K/A				63
CAL.10	20Co/0.5Ru/0.3K/A	142	-	-	83
CAL.11	20Co/0.5Ru/0.3K/A	177	0.34	76	72
CAL.12	20Co/0.5Ru/0.3K/A	175	0.33	75	73
CAL.13	20Co/0.5Ru/0.3K/A	172	0.33	77	81
WGS.02	5Cu/A	159	-	-	-
WGS.03	5Cu/4Cr/A	190	-	-	-
CoW.01	20Co/5Cu/10Zn/A	121	-	-	-
CoW.02	10Co/5Cu/4Cr/A	137	0.27	79	-
CoW.05	20Co/5Cu/4Cr/A	87	0.26	120	-

Table 4. H₂ Chemisorption^a and TPR Results

Catalyst	H ₂ Chemisorption ^a				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average d_p^b (nm)	% Disp.	%Co Red. ^c (TPR calc. catal.)	% Red. ^d (stand. red.)
Co.001	174 $\pm$ 5	157 $\pm$ 5		10.2		
Co.002	155	130		9.1		
Co.003	165	140		9.6		
Co.004 ^f	(1) 205	185	6.9	12.1	91	
	(1) 147	-	9.6	7.4	-	
	(1) 167	-	8.4	8.4	-	
	(2) 126	-	11.1	6.3	64	
	(3) 132	116	10.6	6.6	55	
	(4) 144	123	9.8	7.2	46	
	(5) 136	122	10.3	6.8	41	
Co.005	48	42	20	2.8	89	58
Co.005a	129	110	11	7.6	92	84
Co.006	44	32	19	4	80	
Co.007	33	23	36	2.0	78	78
Co.008						
Co.009	133	109	13	7.8	98	
Co.010						
Co.010a	124	100	12.5	7.3	91	89
Co.011	82	70	15.6	4.8	75	75
Co.012	89	74	15	5.2	80	80
Co.013	21	17	79	1.2	97	
Co.014	38	30	21	3.7	79	
Co.015 ^g	(1) 146	124	11.7	8.6	94	94
	(2) 181	-	7.8	9.1	-	
	(2) 194	-	7.2	9.7	-	
Co.016	163	146	10.5	9.6	96	96
Co.017	202	183	8.5	11.9	97	97
Co.018	185	165	9.2	11	97	94
Co.018Cl ^h					95	

Table 4. H₂ Chemisorption^a and TPR Results (contd.)

Catalyst	H ₂ Chemisorption ^a				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average d _p ^b (nm)	% Disp.	%Co Red. ^c (TPR calc. catal.)	% Red. ^d (stand. red.)
Co.019	112	92		6.6		
Co.020						
Co.020a	153	126	10	9.1	88	
Co.020b	134	113	11	7.9	86	
Co.020c	115	100	13	6.8	88	
Co.021	74	50		4.3		
Co.022	141	122		8.3	80	
Co.023	158	136		9.3	81	
Co.024	87	72		5.1	91	
Co.025	93	77		5.5	75	
Co.026						
Co.027						
Co.028	170	148		10		
Co.029	175	155		7		
Co.030						
Co.031	71	51	20	4.2	82	
Co.032	55	39	26	3.2	85	
Co.033	43	32	31	2.5	79	
Co.034	114	91	14	6.7	96	
Co.035	125	115	11	7.2	82	
Co.036	122	98		7.2		
Co.037	21	3	48	2	99	
Co.038	45	35	21	4.3	91	
Co.039	19	16	40	1.8	72	
Co.040	14	11	53	1.4		
Co.041	70	55		4		

Table 4. H₂ Chemisorption^a and TPR Results (contd.)

Catalyst	H ₂ Chemisorption ^a				TPR	
	Total (μ mol H ₂ /g cat)	Irrev. (μ mol H ₂ /g cat)	Average d_p^b (nm)	% Disp.	%Co Red. ^c (TPR calc. catal.)	% Red. ^d (stand. red.)
Co.043	137	109		8	86	
Co.047	146	-	9.6	7.3		
Co.053 ⁱ	(1) 168 (2) 101 (3) 138	139 76 117	8 14 10	8.4 5.2 6.9	60 82 47	
Co.054					57	
Co.055 ^j	(1) 165 (2) 179 (3) 103 (4) 192	139 163 84 165	8.5 8 14 7	8.3 9.0 5.2 9.6	78 50 76 -	
Co.056					58	
Co.60	65		14.4	2.1		
Co.61	277		7.6	9.2		
CAL.01	169	-	8.3(5.8°)	4.4°	54	
CAL.02	-	-	(6.3°)	5.1°	55	
CAL.03	-	-	5.7°	4.2°	85	
CAL.04	93		15.1(5.5°)	3.5°		
CAL.05	100		14.1(5.6°)	4.4°		
CAL.06			5.7°	4.2°		
CAL.10			7.2°	3.7°		
CAL.11	171		8.3	8.5		
CAL.12	146		9.6	7.3		
CAL.13	180		7.8	9.0		

(a) static H₂ chemisorption at 100°C(b) Est. assuming $H_{tot}/Co_s = 1$, $5.46 \times 10^{-20} \text{ m}^2/Co_s$, and $d_p = 5/S_{Co}/\rho$ S_{Co} is based on amt. Co reducible during standard reduction

(c) % Co reducible from TPR of calcined catalysts up to 900°C

(d) % Co reduced after standard reduction procedure

(e) Based on CO chemisorption

(f) (1)=uncalcined; (2)=flow calcined in air and reduced in H₂; (3)=ROR (4)=calcined in He; (5)=calcined in nitrogen

Table 4. H₂ Chemisorption^a and TPR Results (contd.)

(g) (1)=flow calcined in air; (2)=uncalcined

(h) Co.018Cl = Chlorinated Co.018

(i) (1)=flow calcined in air; (2)=uncalcined; (3)=ROR

(j) (1)=calcined in air; (2)=calcined in nitrogen; (3)=uncalcined; (4)=ROR

Table 5. Summary of Fixed Bed Reactor Data

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ / g cat/hr	R-C6+ g CH ₂ / g cat/hr	R-(CO) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%) (CO)	p/g cat/hr	E act. kcal/ mol	Comment
Co.001	4	(1)	2.6	0.116	0.056	6.8E-04	19.6	0.76	0.4	0.061		NSH**
Co.002	4	(2)	6.7	0.258	0.082	1.5E-03	26.1	0.64	0.1	0.012		NS
Co.003	1	(3)	5.5	0.185	0.044	1.1E-03	30.8	0.57			28.9	old startup
Co.004	1	(2) s	4.3	0.291	0.086	1.7E-03	30.4	0.62	0.1	0.025	25.9	NSH
"	2	u	11.2	0.517	0.155	3.0E-03	28.9	0.61	0.1	0.038		NSH
"	2h	u	47.6	0.548	0.211	3.2E-03	21.9	0.64	2.3	0.090		NSH, high conv. study
"	2a	f	3.8	0.177	0.063	1.0E-03	25.5	0.65	0.1	0.024		NSH, calc. after run 2, T surge
"	3	u	6.7	0.499	0.153	2.9E-03	27.8	0.61	0.1	0.036		NSH
"	3h	u	27.0	0.506	0.164	3.0E-03	27.3	0.62	0.8	0.048		NSH, high conv. study
"	4	u	1.8	0.427	0.241	2.5E-03	24.0	0.79	0.1	0.078		NSH, 10 atm
"	5	f	4.5	0.288	0.150	1.7E-03	19.4	0.75	0.1	0.03		NSH
"	6	n	6.9	0.466	0.151	2.7E-03	27.8	0.61	0.2	0.044		NSH
"	7	ROR	3.9	0.225	0.072	1.3E-03	28.8	0.61	0.2	0.042		NSH
"	8	He	5.8	0.399	0.144	2.3E-03	27.2	0.66	0.1	0.028		NSH
Co.005	2	(1)	3.3	0.087	0.037	5.1E-04	21.4	0.66	0.1	0.005		NS
"	2a		2.5	0.066	0.021	3.9E-04	25.9	0.59	0.1	0.004		CO:H ₂ :Ar = 1:2:2
"	2b		2.4	0.064	0.021	3.7E-04	26.3	0.60	0.1	0.006		+ H ₂ O (eq. 7.5% CO conv.)
"	3		3.3	0.077	0.024	4.5E-04	28.4	0.62	0.1	0.013		NSH
"	4		4.0	0.069	0.021	4.0E-04	30.0	0.62	0.2	0.009	25.1	NSH
"	5		3.9	0.171	0.084	1.0E-03	26.8	0.76	0.1	0.018		NSH, 10 atm
"	6		2.1	0.129	0.044	7.6E-04	25.7	0.64	0.1	0.017		NSH
"	7		6.7	0.084	0.040	4.9E-04	18.8	0.70	0.1	0.003		S ₂
"	8		2.7	0.154	0.067	9.0E-04	22.6	0.71	0.1	0.019		D (1:2), NSH
"	8a		2.5	0.140	0.059	8.4E-04	23.4	0.72	0.1	0.019		Ar added to rxn mix
"	8b		4.2	0.239	0.045	1.4E-03	40.0	0.60	0.1	0.032		Rxn @ 240 °C
"	8c		3.5	0.196	0.026	1.1E-03	49.6	0.59	0.1	0.049		Rxn @ 260 °C
"	8d		2.5	0.140	0.059	8.4E-04	23.4	0.72	0.1	0.019		Rxn @ 280 °C
"	9		1.5	0.082	0.025	4.8E-04	27.7	0.60	0.1	0.014		D (1:4), NSH
"	9a		1.4	0.075	0.020	4.4E-04	29.9	0.61	0.1	0.016		Ar added to rxn mix
"	9b	(1)	1.4	0.078	0.004	4.5E-04	62.9	0.58	0.3	0.055		Rxn @ 280 °C
"	10		1.9	0.106	0.045	6.2E-04	23.0	0.70	0.1	0.016		D (1:2), NSH
"	10a		1.6	0.090	0.024	5.3E-04	25.3	0.68	0.1	0.017		Ar added to rxn mix
"	10b		1.8	0.100	0.005	5.9E-04	48.0	0.65	0.2	0.037		Rxn @ 280 °C
"	10c		0.4	0.024	0.010	2.3E-04	25.9	0.76	0.1	0.013	13.8	at 220 after rxn @ 280
Co.005a	1	(4a)	3.2	0.227	0.067	1.3E-03	30.0	0.60	0.1	0.034		NSH
Co.005b	1	(1)	2.4	0.040	0.024	2.3E-04	13.9	0.74	0.4	0.023		S ₂ , 1/4WGS.03 + 3/4Co.005
Co.005c	1	(1)	5.7	0.071	0.031	4.1E-04	20.3	0.68	1.8	0.076		S ₂ , 1/2WGS.03 + 1/2Co.005
Co.006	1	(5)	2.7	0.052	0.007	5.1E-04	45.0	0.49	0.1	0.006		NSH
Co.007	1	(5)	3.2	0.024	33	7.0E-03	49.8	0.50	0.2	0.004		NSH
Co.009	1	(1)	4.9	0.346			31.1	0.57	0.1	0.020		NSH
"	2		4.9	0.338			31.1	0.58	0.1	0.026		NSH
Co.010a	1	(4b) s	3.5	0.246	0.076	1.4E-03	29.5	0.62	0.2	0.040		NSH
"	2		4.1	0.262	0.080	1.5E-03	30.0	0.61	0.1	0.022		NSH

Table 5. Summary of Fixed Bed Reactor Data (cont. 'd)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/hr	R-C6+ g CH ₂ /g cat/hr	R (Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%)	g/g cat/hr	E act. kcal/ mol	Comment
Co.011	2	(6b)	2.9	0.094	0.037	5.5E-04	22.4	0.61	0.3	0.030		NSH
Co.012	1	(1)	3.8	0.083	0.027	4.8E-04	26.3	0.64			22.5	slow CO startup (60 min)
"	2		4.4	0.085	0.030	5.0E-04	29.1	0.64	0.3	0.018		NSH
"	3		2.1	0.081	0.026	4.7E-04	28.6	0.66	0.4	0.049		NSH
"	4		2.5	0.105	0.035	6.2E-04	28.4	0.61	0.4	0.023		NSH
Co.014	1	(1)	1.5	0.028	0.009	2.8E-04	32.3	0.63	0.1	0.003		NSH
"	2		2.6	0.034	0.013	3.3E-04	27.7	0.69	0.1	0.011	26.0	NSH
Co.015	1	(4) s	6.8	0.211	0.063	1.2E-03	26.7	0.60	0.1	0.011		slow CO startup (120 min)
"	2	f	7.0	0.388	0.135	2.3E-03	26.4	0.64	0.1	0.011		NSH
"	3	u	6.7	0.375	0.123	2.2E-03	28.2	0.63	0.2	0.011		NSH
Co.016	1	(4a) s	5.2	0.161	0.035	9.4E-04	33.6	0.56				slow CO startup (30 min)
"	2	f	5.1	0.291	0.112	1.7E-03	25.1	0.68	0.1	0.01		NSH
Co.017	2	(1) s	4.6	0.139	0.066	8.2E-04	22.0	0.69	0.1	0.012		NS
"	2a	s	3.7	0.111	0.043	6.5E-04	25.9	0.64	0.1	0.011		CO:H ₂ :Ar = 1:2:2
"	2b	s	3.4	0.102	0.039	6.0E-04	26.9	0.65	0.1	0.013		+ H ₂ O (eq. 7.5% CO conv.)
"	3	f	4.9	0.274	0.111	1.6E-03	23.0	0.67	0.2	0.030		NSH, calc. flow air
Co.018	2	s	3.4	0.170	0.068	1.0E-03	27.2	0.69	0.1	0.013		NS
"	2a	s	2.7	0.133	0.041	7.8E-04	33.2	0.64	0.1	0.011		CO:H ₂ :Ar = 1:2:2
"	2b	s	3.0	0.147	0.045	8.6E-04	33.6	0.63	0.1	0.015		+ H ₂ O (eq. 7.5% CO conv.)
"	3	s	4.1	0.290	0.086	1.7E-03	30.0	0.62	0.1	0.022		NSH
"	4	s	3.6	0.340	0.180	2.0E-03	25.4	0.80	0.1	0.041		NSH, 10 atm
"	5	f	7.5	0.470	0.136	2.8E-03	29.0	0.60	0.3	0.055		NSH
Co.018Cl	1	(1)	4.5	0.320	0.075	1.9E-03	33.5	0.57	0.1	0.018		NSH
Co.019	1	(1)s	4.4	0.088	0.047	5.2E-04	15.2	0.74				NS
"	2	s	2.2	0.085	0.046	4.9E-04	18.9	0.73	0.3	0.040		NSH
"	3	f	3.4	0.142	0.071	8.3E-04	19.3	0.72	0.2	0.025		NSH
Co.020a	1	(4) s	4.6	0.343	0.085	2.0E-03	33.5	0.57	0.1	0.024		NSH
"	2		4.4	0.315	0.086	1.8E-03	31.2	0.59	0.1	0.028		NSH
Co.020b	1	(4b) s	4.4	0.311	0.084	1.8E-03	31.7	0.58	0.2	0.051		NSH
Co.020c	1	(4a) s	4.0	0.287	0.083	1.7E-03	30.4	0.60	0.1	0.017		NSH
Co.021	1	(6b)	3.4	0.109	0.032	6.4E-04	27.3	0.62	0.1	0.012	28.2	NSH
"	2		3.6	0.114	0.035	6.7E-04	28.0	0.56	0.1	0.012		NSH
Co.022	1	(6c)	3.8	0.121	0.037	7.1E-04	26.7	0.55	0.1	0.015	30.1	NSH
Co.023	1	(6c)	3.8	0.123	0.038	7.2E-04	28.3	0.56	0.2	0.023	29.5	NSH
Co.024	1	(7)	5.1	0.165	0.047	9.7E-04	32.8	0.62	0.5	0.055		NSH
"	2		5.7	0.182	0.060	1.1E-03	28.7	0.62	0.3	0.035		NSH
Co.025	1	(4)	5.0	0.160	0.062	9.4E-04	23.5	0.63	0.2	0.019	26.9	NSH
"	2		2.0	0.113	0.037	6.6E-04	26.8	0.61				NSH
"	2a		0.7	0.040	0.007	2.3E-04	49.5	0.66				Rxn @ 280 °C
Co.026	1	(1)	4.4	0.129	0.043	5.0E-04	26.9	0.62	0.2	0.022		NSH
"	1h		22.9	0.170	0.072	6.6E-04	22.6	0.67	1.5	0.037		NSH, high conv. study
Co.027	1	(1)	4.2	0.169	0.068	6.6E-04	23.0	0.65	0.2	0.026		NSH
"	1h		17.8	0.180	0.085	7.0E-04	19.4	0.71	1.2	0.011		NSH, high conv. study

Table 5. Summary of Fixed Bed Reactor Data (cont. 'd)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ /g cat/hr	R-C6+ g CH ₂ /g cat/hr	R (Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%)	g/g cat/hr	E act. kcal/ mol	Comment
Co.028	1	(4)	3.8	0.146	0.076	5.7E-04	18.2	0.76	0.2	0.031	28.4	NSH
"	2		4.3	0.167	0.105	6.5E-04	14.7	0.80	0.2	0.030		NSH
"	3		4.5	0.206	0.126	8.0E-04	15.5	0.79	0.2	0.037		NSH, re-calc. in flow air
Co.029	1	(4)	2.8	0.173	0.105	6.7E-04	15.3	0.79	0.2	0.026		NSH
Co.031	1	(1)	1.9	0.060	0.022	3.5E-04	26.1	0.64	0.3	0.031		NSH
Co.032	1	(1)	3.3	0.183	0.079	1.1E-03	22.0	0.70	0.1	0.022		NSH
Co.033	1	(1)	1.3	0.073	0.027	4.3E-04	24.1	0.67	0.1	0.020		NSH
Co.034	1	(4)	5.0	0.275	0.107	1.6E-03	24.0	0.67	0.1	0.018		NSH
Co.035	2	(6)	4.6	0.147	0.068	8.6E-04	22.0	0.69	0.2	0.019		NSH
Co.036	2	(6c)	3.9	0.125	0.045	7.3E-04	28.9	0.67	0.1	0.013		NSH
Co.037	1	(4a)	2.7	0.053	0.011	5.2E-04	32.8	0.59				NSH
Co.038	1	(4a)	4.5	0.051	0.018	4.9E-04	25.1	0.68	0.3	0.013	24.2	NSH
Co.039	1	(5)	1.1	0.021	0.004	2.0E-04	57.2	0.64	0.2	0.010	25.6	NSH, cracking in the line
"	2		3.9	0.049	0.007	4.7E-04	42.4	0.48	0.2	0.009		NSH
Co.040	1	(4a)	1.9	0.037	0.004	3.7E-04	45.2	0.53	0.2	0.007		NSH
"	2		2.8	0.033	0.004	3.3E-04	44.6	0.46	0.2	0.007		NSH
Co.041	1	(4)	3.5	0.136	0.042	8.0E-04	40.7	0.69	0.6	0.079		NSH, cracking in the line
Co.043	1	(4a)	4.6	0.104	0.062	6.1E-04	15.3	0.78	0.6	0.048	35.1	NSH, 2.5 hr on-stream
"	2		3.7	0.078	0.045	4.6E-04	16.3	0.78	0.5	0.035		NSH
Co.044	1	(4)	3.1	0.179	0.081	1.0E-03	22.7	0.73	0.3	0.020		NSH
Co.045	1	(4)	2.6	0.161	0.076	9.4E-04	22.2	0.73	0.3	0.022		NSH
Co.047	1	(4)	6.4	0.263	0.128	1.5E-03	21.3	0.73	0.3	0.040	26.6	NSH
Co.048	1	(4)	3.5	0.162	0.094	9.5E-04	16.3	0.77	0.2	0.027	28.0	NSH
Co.049	1	(4)	7.1	0.366	0.153	2.1E-03	23.4	0.69	0.3	0.043		NSH
"	2		6.0	0.388	0.160	2.3E-03	23.3	0.68	0.3	0.056		NSH, re-calcined in flow air
"	3	f	6.7	0.410	0.158	2.4E-03	25.2	0.69	0.3	0.059		NSH
"	3h	f	44.9	0.457	0.178	2.7E-03	26.5	0.67	3.8	0.131		NSH,HCS
Co.053	1	(1)	7.0	0.408	0.127	2.4E-03	27.3	0.62	0.2	0.049		NSH
"	1h		28.5	0.417	0.145	2.4E-03	26.8	0.64	1.6	0.081		NSH, high conv. study
"	2	f	6.6	0.433	0.174	2.5E-03	23.4	0.63	0.2	0.052		NSH
"	3		7.8	0.453	0.143	2.7E-03	27.6	0.62	0.1	0.027		NSH
"	3h		31.5	0.457	0.164	2.7E-03	25.4	0.65	0.9	0.044		NSH, high conv. study
"	4	u	6.1	0.426	0.142	2.5E-03	28.3	0.65	0.1	0.030		NSH
"	5	ROR	5.6	0.360	0.118	2.1E-03	27.9	0.64	0.2	0.034		NSH, ROR
"	6	f	8.2	0.485	0.163	2.8E-03	28.9	0.64	0.1	0.030		NSH
"	7	f	9.4	0.552	0.147	3.2E-03	34.3	0.60	0.1	0.044		NSH, Rxn @ 227 °C
"	7a	f	1.7	0.099	0.018	5.8E-04	38.1	0.60	0.2	0.028		xn @ 245 °C, T surge 280 °C
"	7b	f	2.0	0.119	0.031	7.0E-04	32.1	0.62	0.1	0.021		cal(5 hr) & red after run 7
"	8	f	7.7	0.450	0.144	2.6E-03	30.3	0.65	0.1	0.036		NSH
"	8a	f	6.3	0.368	0.103	2.2E-03	32.8	0.65	0.1	0.047		Ar added to the rxn mix.
"	8b	f	3.0	0.177	0.037	1.0E-03	37.3	0.65	0.1	0.033		xn @ 240 °C, T surge 275 °
"	9	f	4.3	0.470	0.225	2.8E-03	21.6	0.69	0.2	0.046		D (1:2), NSH
"	9a	f	7.5	0.411	0.067	2.4E-03	46.9	0.62	0.2	0.070		Ar added to the rxn mix.
"	9b	f	11.9	0.647	0.116	3.8E-03	42.7	0.59	0.1	0.046		Rxn @ 240 °C

Table 5. Summary of Fixed Bed Reactor Data (cont. 'd)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ / g cat/hr	R-C6+ g CH ₂ / g cat/hr	R (Co) mol/mol Co/s	wt% CH ₄	alpha	CO ₂ (%)	g/g cat/hr	E act kcal/ mol	Comment
Co.053	10		5.6	0.304	0.091	1.8E-03	29.2	0.60	0.2	0.008		D(1:2) , NSH
"	10a		11.9	0.647	0.116	3.8E-03	42.7	0.59	0.2	0.046		Rxn @ 240 °C
"	10b		7.5	0.411	0.067	2.4E-03	46.9	0.62	0.4	0.070		Rxn @ 260 °C
"	10c		3.0	0.163	0.035	9.6E-04	38.8	0.69	0.3	0.054		Rxn @ 280 °C
"	11		5.4	0.289	0.102	1.7E-03	26.9	0.64	0.1	0.022		D (1:2) ,NSH
"	11a		3.8	0.205	0.047	1.2E-03	38.7	0.69	0.3	0.060		Rxn @ 280 °C
"	12	f	8.1	0.433	0.145	2.5E-03	26.6	0.60	0.2	0.029		D (1:2) ,NSH
"	12a	f	5.3	0.283	0.063	1.7E-03	39.4	0.69	0.4	0.083		Rxn @ 280 °C
"	12b	f	1.4	0.080	0.054	4.7E-04	20.0	0.78	0.1	0.02		Rxn @ 220
"	13	f	8.3	0.444	0.143	2.6E-03	29.3	0.65	0.2	0.037		Cal(10hr) & red after run 12
"	14		6.7	0.375	0.161	2.2E-03	24.8	0.74	0.1	0.025		Cal(24hr) & red after rxn @EI
Co.054	1	(1)	1.2	0.041	0.023	2.4E-04	17.8	0.79	0.2	0.014		NSH
Co.055	1	(1) f	9.1	0.490	0.159	2.9E-03	28.9	0.63	0.2	0.034		NSH
"	2	u	4.9	0.290	0.105	1.7E-03	25.7	0.65	0.2	0.022		NSH, T surge
"	3	u	11.0	0.611	0.193	3.6E-03	29.4	0.60	0.2	0.033		NSH
"	4	u	5.9	0.380	0.124	2.2E-03	28.3	0.60	0.2	0.047		NSH
"	5	u	6.6	0.409	0.135	2.4E-03	29.6	0.59	0.2	0.030		NSH
"	6	ROR	7.5	0.469	0.145	2.7E-03	30.9	0.63	0.2	0.023		NSH
"	7	n	7.5	0.466	0.119	2.7E-03	33.5	0.60	0.2	0.031		NSH
"	8		6.1	0.344	0.108	2.0E-03	29.7	0.66				NSH
"	8a		0.7	0.037	0.005	2.3E-04	41.2	0.66				Rxn @ 280 °C
Co.056	1	(1)	2.4	0.137	0.054	8.0E-04	23.9	0.69	0.1	0.029		NSH
"	2	u	2.2	0.137	0.054	8.0E-04	23.4	0.68	0.1	0.033		NSH
Co.057	1	(1)	2.8	0.171	0.078	1.0E-03	23.4	0.73	0.1	0.029		NSH
Co.060	1	(2)	3.8	0.244	0.097	1.4E-03	25.0	0.69	0.1	0.023		NSH
Co.061	1	(2)	9.4	0.556	0.188	3.3E-03	29.2	0.67	0.1	0.035		NSH
Co.064	1	(2)	7.1	0.384	0.130	2.2E-03	27.5	0.64	0.1	0.028		NSH
Co.066	1	(1)	1.7	0.100	0.031	7.8E-04	27.7	0.67				NSH
"	1a		0.9	0.050	0.009	3.9E-04	32.9	0.68				Rxn @ 280 °C
Co.067	1	(1)	2.2	0.130	0.045	7.5E-04	25.0	0.67				NSH
"	1a		1.6	0.090	0.010	5.2E-04	46.9	0.61				Rxn @ 280 °C
Co.068	1	(1)	4.0	0.220	0.065	1.3E-03	28.8	0.62				NSH
"	1a		1.7	0.100	0.010	6.8E-04	42.7	0.57				Rxn @ 280 °C
CAL.01	1	(1)	4.8	0.181	0.068	1.1E-03	24.4	0.66	0.3	0.036		NSH, temp. surge (startup)
"	2		7.4	0.491	0.142	2.9E-03	28.7	0.61	0.4	0.083		NSH
"	3		2.5	0.164	0.053	9.6E-04	25.6	0.63	0.2	0.052		NSH, HT, re-reduced
"	4		7.3	0.483	0.103	2.8E-03	35.8	0.57	0.2	0.098		NSH, HT, re-calcined
CAL.02	1	(1)	6.1	0.379	0.121	2.2E-03	27.3	0.63	0.2	0.040		NSH
CAL.03	1	(1)	7.3	0.459	0.133	2.7E-03	29.0	0.60	0.2	0.048		NSH
CAL.04	1	(1)	4.1	0.234	0.123	1.4E-03	19.1	0.71	0.2	0.026		NSH
CAL.05	1	(1)	4.7	0.274	0.134	1.6E-03	20.8	0.75	0.2	0.026		NSH
CAL.06	1	(1)	5.8	0.267	0.135	1.6E-03	20.7	0.74	0.2	0.021		NSH
CAL. 10	1	(1)	3.5	0.196	0.097	1.1E-03	23.5	0.74	0.2	0.05		NSH

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

Catalyst	Run	Prep	CO Conv (%)	Rate g CH ₂ / g cat/hr	R-C6+ g CH ₂ / g cat/hr	R (Co) mol/mol C ₆ s	wt % CH ₄	alpha	CO ₂ (%)	g/g cat/hr	E act kcal/ mol	Comment
CAL.02	1	(1)	6.1	0.379	0.121	2.2E-03	27.3	0.63	0.2	0.040		NSH
CAL.03	1	(1)	7.3	0.459	0.133	2.7E-03	29.0	0.60	0.2	0.048		NSH
CAL.04	1	(1)	4.1	0.234	0.123	1.4E-03	19.1	0.71	0.2	0.026		NSH
CAL.05	1	(1)	4.7	0.274	0.134	1.6E-03	20.8	0.75	0.2	0.026		NSH
CAL.06	1	(1)	5.8	0.267	0.135	1.6E-03	20.7	0.74	0.2	0.021		NSH
CAL.10	1	(1)	3.5	0.196	0.097	1.1E-03	23.5	0.74	0.2	0.05		NSH
CAL.11	1	(1)	5.2	0.281	0.147	1.6E-03	20.0	0.75	0.2	0.029		NSH
CAL.12	1	(1)	5.2	0.288	0.143	1.7E-03	21.6	0.73	0.2	0.035		NSH
CAL.13	1	(1)	4.6	0.258	0.142	1.5E-03	18.0	0.77	0.2	0.024		NSH
CoW.01	1	(4a)	1.2	0.016	0.003	9.5E-05	30.2	0.58	0.2	0.006		NSH, reduced at 230 °C
"	1		0.5	0.007	0.001	3.4E-05	42.1	0.51	0.1	0.003		NSH, re-reduced at 350 °C
"	2		0.2	0.006	0.000	3.4E-05	40.9	0.51	0.1	0.006		NSH, reduced at 350 °C
CoW.02	1	(4a)	0.3	0.009	0.002	5.4E-05	25.6	0.60	0.1	0.008		NSH, reduced at 230 °C
CoW.03	1	(4a)										NSH, negligible activity
CoW.04	1	(4a)										S2, negligible activity
CoW.05	1	(4c)	2.8	0.035	0.006	2.1E-04	33.1	0.55	0.2	0.008		S2, reduced at 350 °C
"	2	u	4.7	0.058	0.011	3.4E-04	34.8	0.50	0.2	0.009		S2
"	3	(4c)	0.8	0.020	0.005	1.2E-04	32.8	0.64				NSH
"	3a	(4c)	3.5	0.100	0.008	6.0E-04	54.2	0.58				Rxn @ 280°C
CoW.06	1	(4a)	3.3	0.041	0.012	2.4E-04	26.0	0.59	0.2	0.007		S2, reduced at 250 °C
"	2	u	2.6	0.032	0.004	1.9E-04	39.3	0.46	0.3	0.012		S2
CoW.06	2		17.0	0.207	0.004	1.2E-03	68.7	0.32	1.7	0.07		S2, rxn. at 280 °C
UOP	1	(1)	7.8	0.298	0.104	1.7E-03	22.6	0.61	0.2	0.023		NSH

Table 5. Summary of Fixed Bed Reactor Data (cont.'d)

Reaction Conditions: $T = 220^{\circ}\text{C}$, $\text{H}_2:\text{CO} = 2, 1 \text{ atm}$

All the catalysts are reduced and passivated before loading into reactor, then rereduced in-situ

All catalysts are calcined at UPARC (static) : except where specified in prep. column

s : calcined at Pitt, static

f : calcined at Pitt, flow

u : uncalcined

n : Nitrogen calcined

In some cases, "re-calcined" means calcination of the calcined catalyst from UPARC for a longer period

(1) single step, aqueous incipient wetness

(2) Two step impregnation: aqueous incipient wetness of Co + acetone/ethanol impregnation of Ru, La

(3) three step, with calcination after each step, acetone incipient wetness

(4) two step, aqueous incipient wetness, (a) intermediate calcination, (b) intermediate reduction,
(c) intermediate calcination 750°C

(5) single step, acetone impregnation

(6) single step, aqueous kneading, (a) = 150%, (b) = 110% of pore volume

(6c) aqueous kneading for Co, calcined, then aqueous incipient wetness for Zr

(7) Two step impregnation : organic incipient wetness + aqueous incipient wetness

NS New startup

NSH New startup, heated inlet

S2 was done in the second system

~ Davison Grade 59 Silica, if not specified, S refers Davison Drade 952 Silica

corrected overheated line on 3/6/1994

D (x:y) Catalyst bed dilution with x parts cat. and y parts -alumina

Co.018Cl Chlorinated Co.018

COMPARISON OF CONVERSION AND SELECTIVITY OF
COBALT BASED F-T CATALYSTS AT STARTUP CONDITIONS

		Period No.		Temp.		Pres.		H2/CO Ratio					
		-----		-----		-----		-----					
		1		240 C		450psi		2.0					

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Catalyst Prom%	Composit. Metal% Suppt	

M-3 SBCR													
5	CO.003	15.1	31.7	1.53	16.7	2.4	79.8	1.16	0.71	--	1.0La	0.5Ru	Al
6	CO.011	15.3	14.3	0.67	7.6	1.6	89.4	1.42	0.78	0.83	0.0	0.0	Si
7	CO.012	15.8	13.9	0.63	6.1	1.5	90.6	1.74	0.80	0.89	0.0	0.0	Si
8	CO.015	15.0	28.3	1.37	12.7	2.0	84.1	1.24	0.76	0.80	1.0La	0.43Ru	Al
9	CO.011	15.0	18.5	0.89	8.8	1.7	88.8	0.77	0.78	0.83	0.0	0.0	Si
11	CO.017	15.0	27.2	1.32	11.2	1.8	85.9	1.14	0.77	0.80	1.0La	0.5Ru	Al
12	CO.018	15.6	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	0.0	0.5Ru	Al
13	CO.016	14.7	26.4	1.31	(1)	1.7	89.3	0.68	0.78	0.81	1.0La	0.43Ru	Al
14	CO.019	15.2	13.9	0.66	(2)	1.7	97.2	0.70	0.80	0.86	0.0	0.5Ru	Si
15	CO.005	14.7	27.1	1.34	7.9	1.6	89.7	0.82	0.79	0.82	0.0	0.0	Al
16	CO.002	15.4	30.1	1.42	12.5	2.5	83.9	1.09	0.75	0.80	1.0La	0.43Ru	Al
17	CO.025	15.6	26.6	1.24	10.7	2.1	86.4	0.82	0.76	0.82	8.5Zr	0.0	Si
18	CO.004	15.0	33.9	1.64	15.3	2.4	80.9	1.37	0.74	0.79	1.0La	0.43Ru	Al
19	CO.021	15.6	23.2	1.08	9.4	2.0	88.0	0.73	0.77	0.82	0.7Zr	0.0	Si
20	CO.041	15.8	25.3	1.16	11.0	2.1	86.0	0.88	0.76	0.84	8.5Zr	0.5Ru	Si
21	CO.014	15.1	8.5	0.40	8.3	3.5	85.8	2.43	0.74	0.83	0.0	0.5Ru	Ti
22	CO.040	14.5	1.8	0.09	0.0	4.0	94.1	1.89	0.71	0.82	0.0	0.0	Ti
23	CO.047	15.8	28.2	1.29	7.7	1.5	89.3	1.47	0.79	0.84	0.3K	0.5Ru	Al
24	CO.049	15.6	30.6	1.41	10.9	1.8	85.7	1.66	0.76	0.82	0.1K	0.5Ru	Al
25	CO.047	15.6	28.1	1.30	8.8	1.6	88.1	1.50	0.78	0.85	0.3K	0.5Ru	Al
26	CO.031	15.9	30.9	1.41	12.1	1.9	84.9	1.12	0.75	0.83	1.4Zr	0.0	Al
27	CO.029	15.9	28.3	1.27	8.3	1.6	87.9	2.21	0.77	0.84	0.5K	0.5Ru	Al
28	COW.01	15.0	1.1	0.05	0.0	12.	83.9	4.23	0.58	--	5.0Cu	10.0Zn	Al
29	CO.053	25.2	42.0	1.19	15.8	2.3	79.5	2.42	0.73	--	0.0	0.5Ru	Al
30	CO.053	29.6	41.8	1.02	22.6	2.9	71.5	3.05	0.66	0.77	0.0	0.5Ru	Al
31	CO.055	15.0	30.0	1.46	23.7	3.7	70.2	2.30	0.61	0.81	1.0La	1.0Re	Al
32	CO.044	16.4	20.9	0.93	6.7	1.9	90.8	0.56	0.77	0.83	15.0Zr	0.0	Si
33	CO.053	31.4	41.4	0.94	23.2	3.1	69.6	4.06	0.65	0.76	0.0	0.5Ru	Al
34	CO.060	15.6	31.4	1.46	14.0	2.3	82.2	1.48	0.75	0.79	0.0	0.0	Al
35	CO.041	26.0	35.7	1.00	13.6	2.1	82.9	1.41	0.79	0.82	8.5Zr	0.5Ru	Si
36	CO.032	15.9	24.0	1.10	9.1	1.8	88.2	0.83	0.77	0.83	8.5Zr	0.0	Al
37	CO.045	15.9	14.8	0.67	8.0	1.7	89.4	0.91	0.76	0.84	4.0Zr	0.0	Si
38	Co.058	15.9	28.0	1.28	11.9	2.1	85.1	0.91	0.75	0.85	1.0La	0.0	Al
39	Co.064	15.9	34.2	1.56	13.6	2.3	82.6	1.55	0.73	0.85	8.5Zr	0.5Ru	Al

Note: Catalyst Run 9 screened thru 170 x 400 mesh.
Catalysts For Runs 11 through 28 (except Runs 21 and 22) screened thru 150x 400 mesh.
Catalysts for Runs 21 and 22 screened thru 100 x 400 mesh.
Catalyst No. CO.029 contained 30 wt% cobalt.

G.C. Problems

- (1) Weak TCD filaments in G.C. CH₄ peaks smaller than expected.
- (2) Internal valve in G.C. leaked. CH₄ peak undetected.

Table 6
(continued)

DATE: 07/12/95

COMPARISON OF CONVERSION AND SELECTIVITY OF
COBALT BASED F-T CATALYSTS AT STARTUP CONDITIONS

Period No.				Temp.		Pres.		H2/CO Ratio					
-----				-----		-----		-----					
1				240 C		450psi		2.0					

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Catalyst Prom%	Composit. Metal% Suppt	

M-3 SBCR													
40	Co.063	15.0	8.7	0.43	6.5	0.9	92.6	0.09	0.74	--	8.5La	0.0	Al
41	Co.062	15.0	6.6	0.32	3.5	0.3	95.3	1.00	0.76	0.89	1.5K	0.5Ru	Al
42	Co.065	15.9	27.6	1.25	7.9	2.0	88.6	1.61	0.79	0.84	8.5Zr 0.3K	0.5Ru	Al
43	COW.12	9.1	6.1	0.47	20.3	6.1	66.3	7.3	0.61	0.83	0.0	0.5Ru	Si
44	COW.11	15.6	4.7	0.20	8.4	6.3	74.4	10.9	0.60		0.5K	0.5Ru	Al
45	Fe.01	15.9	3.4	0.14	0.0	7.5	84.8	7.72	0.72	0.77	0.0	1.5Cu	Si
46	COW.05	15.7	4.9	0.23	10.9	6.5	81.9	0.74	0.60		4.0Cr	5.0Cu	Al
47	Co.070	15.6	22.8	1.07	10.9	2.7	85.7	0.70	0.75	0.85	0.0	0.0	Al

Note: All catalysts except COW.12 were screened thru 150 x 400 mesh.

Catalyst No. COW.12 contains 10% Co plus 10% Fe.

Catalyst No. COW.11 contains 10% Co plus 10% Fe. It is 150 x400 mesh.

Catalyst No. Fe.01 contains 30% Fe and no cobalt.

Catalyst No. Co.070 contains 13% Co with no promoters.

Table 7

ANALYSES OF RECOVERED SBCR
CATALYSTS FOR CARBON CONTENT

<u>Run No.</u>	<u>Catalyst No.</u>	<u>Charge</u> gm	<u>Metals</u> wt %	<u>Promoter</u> wt %	<u>Support</u>	<u>CO Conv.</u> wt %	<u>Carbon</u> wt %
3008	Co.015	15.0	1.0 La	0.43 Ru	Al	28.3	9.4
3009	Co.011	15.0	0	0	Si	18.5	5.3
3011	Co.017	15.0	1.0 La	0.5 Ru	Al	27.2	6.6
3013	Co.016	14.7	1.0 La	0.43 Ru	Al	26.4	1.7
3016	Co.002	15.4	1.0 La	0.43 Ru	Al	30.1	8.1
3017	Co.025	15.6	8.5 Zr	0	Si	26.6	0.5
3018	Co.004	15.0	1.0 La	0.43 Ru	Al	33.9	8.3
3029	Co.053	25.2	0	0.5 Ru	Al	42.0	5.9
3030	Co.053	29.6	0	0.5 Ru	Al	41.8	13.5
3031	Co.055	15.0	1.0 La	1.0 Re	Al	30.0	6.9

Note: All catalysts were tested at 240°C reaction temperature except RN3029 was tested up to 260°C, and RN3030 had reached a maximum of 320°C reaction temperature.

Table 8

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	(Oxidized) wt, gm	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	
Co.001 (Al)	1	14.5	12.63	42.02	24.25	41.06	23.62	2.3
Co.001 (Al)	2	16.5	15.18	42.02	24.25	40.09	22.86	4.6
Co.005 (Al)	3	19.5	18.41	85.66	30.46	64.53	31.27	24.7
Co.002 (Al)	4	20.1	20.4	73.61	32.86	71.19	33.50	3.3
Co.003 (Al)	5	15.1	14.54	76.81	34.40	72.57	34.25	5.5
Co.011 (Si)	6	15.3	16.03	107.09 (1)	53.19	94.02	40.44	12.2
Co.012 (Si)	7	15.8	14.73	105.22 (1)	51.33	101.37	44.44	3.7
Co.015 (Al)	8	15.0	15.52	75.63 (1)	33.15	74.68	32.68	1.3
Co.011 (Si)	9	15.0	15.92	79.00 (2)	48.31	72.44	36.31	9.3
Co.016 (Al)	10	15.5	15.72	64.60 (2)	32.16	64.30	32.70	0.3
Co.017 (Al)	11	15.0	15.09	73.14 (3)	36.29	69.95	35.62	4.4
Co.018 (Al)	12	15.6	16.97	62.89 (3)	32.56	68.16	34.74	--
Co.016 (Al)	13	14.7	13.30	67.69 (3)	35.05	64.79	34.20	4.3
Co.019 (Si)	14	15.2	15.00	92.63 (3)	42.73	84.39	36.52	8.9
Co.005 (Al)	15	14.7	15.30	80.62 (3)	45.07	71.90	36.79	10.8
Co.002 (Al)	16	15.4	14.98	73.61 (3)	32.86	67.62	32.67	8.1
Co.002 (Al)	1 (M4)	15.0	11.00	73.61 (3)	32.86	66.26	35.75	10.0
Co.025 (Si)	17	15.6	14.60	87.19 (3)	47.35	78.31	36.27	10.2
Co.004 (Al)	18	15.0	15.25	78.12 (3)	44.15	66.86	33.83	14.4
Co.021 (Si)	19	15.6	16.06	86.18 (3)	46.54	77.95	35.59	9.55
Co.041 (Si)	20	15.8	17.02	87.48 (3)	49.26	68.74	26.72	17.0
Co.021 (Si)	3 (M4)	15.2	15.1	73.61 (3)	24.46	71.38	32.33	3.03
Co.024 (Al)	4 (M4)	15.4	(4)	--	--	--	--	--
Co.035 (Si)	5 (M4)	15.4	14.08	89.14 (3)	49.29	74.76	31.67	19.2
Co.028 (Al)	6 (M4)	15.4	15.7	80.83 (3)	44.01	71.83	36.34	11.1

(1) Screened through 100x400 mesh screens.

(2) Screened through 170x400 mesh screens.

(3) Screened through 150x400 mesh screens.

(4) Did not filter, too waxy

Note: The charge weights are in the hydrogen-reduced state and the recovered weights are in the oxidized state. The particle size is reported as the mean volume diameter (mvd) as measured by a Microtrac particle size analyzer.

Table 8
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Recovered		Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm		(Oxidized) wt, gm		Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd. microns	Particle Size at 10% microns	
Co.014 (Ti)	21	15.1		15.1		111.70 (1)	32.65	106.66	33.49	4.51
Co.040 (Ti)	22	14.5		8.5		(5)	(5)	130.40	51.40	--
Co.047 (Al)	23	15.8		16.95		83.42 (3)	44.41	76.46	39.02	8.34
Co.049 (Al)	24	15.6		16.54		81.3 (3)	42.39	70.11	35.87	13.8
Co.047 (Al)	25	15.6		16.69		79.36 (3)	41.72	69.09	36.16	12.94
Co.031 (Al)	26	15.9		15.37		75.40 (3)	38.34	68.42	35.39	9.35
Co.029 (Al)	27	15.9		18.28		76.39 (3)	39.56	68.72	36.04	10.04
Co.043 (Si)	7 (M4)	15.4		15.1		(5)	(5)	85.51	40.20	--
Co.006 (Ti)	8 (M4)	15.0		9.09		121.38 (1)	52.80	99.31	38.62	18.2
Co.048 (Si)	9 (M4)	15.4		15.85		82.40 (3)	40.94	70.69	25.53	14.2
CAL.02 (Al)	10 (M4)	15.9		16.42		74.40 (3)	37.79	65.89	34.14	11.44
Co.053 (Al)	12 (M4)	15.9		16.95		82.02 (3)	43.10	69.53	35.76	15.23
Co.054 (Si)	13 (M4)	15.7		17.09		101.17 (3)	57.54	82.37	37.89	18.58
Blend A (Al)	14 (M4)	20.0		14.61		86.23 (3)	46.36	77.43	42.81	10.21
Co.034 (Al)	15 (M4)	13.0		9.52		(5)	(5)	88.26	45.28	--
CAL.04 (Al)	16 (M4)	16.1		21.78		71.54 (3)	36.28	66.50	32.82	7.05
CAL.08 (Al)	17 (M4)	15.0 (6)		14.27		63.12	25.60	62.80	26.03	0.51
CAL.07 (Al)	18 (M4)	14.5 (6)		13.37		--	--	67.02	28.12	--
CAL.05 (Al)	19 (M4)	15.7		5.62		72.75	36.90	71.62	36.55	1.55
CAL.06 (Al)	20 (M4)	15.0		(7)		72.62	37.33	--	--	--
Co.053 (Al)	29 (M3)	25.2		25.8		75.63	40.80	71.09	38.20	6.00
Co.004 (Al)	21 (M4)	15.9		15.04		81.30	41.82	72.88	37.61	10.44

-
- (1) Screened through 100x400 mesh screens.
 - (3) Screened through 150x400 mesh screens.
 - (5) Insufficient feed sample.
 - (6) Wax coated.
 - (7) Lost catalyst.

Table 8.
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge	Recovered	Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	(Oxidized) wt, gm	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	
Blend B (Al)	22 (M4)	30.5	31.75	77.85	43.10	73.74	38.80	5.28
CAL.09 (Al)	23 (M4)	30.0 (6)	14.34	63.12	25.60	62.10	26.32	1.62
Co.053-3 (Al)	24 (M4)	28.5	27.85	75.63	40.80	70.69	35.03	6.53
Co.055 (Al)	31 (M3)	15.0	14.67	85.58	46.27	74.56	39.00	12.88
Co.056 (Si)	25 (M4)	15.0	14.93	99.93	54.62	88.48	43.26	11.46
Co.044 (Si)	32 (M3)	16.4	17.01	92 15	49.30	84.92	40.21	7.85
CAL.10 (Al)	26 (M4)	15.6	14.63	83.05	47.11	81.12	45.87	2.32
Co.053-4 (Al)	33 (M4)	31.4	31.9	84.09	44.40	73.50	37.10	12.6
Co.050 (Al)	27 (M4)	14.6	10.62	(5)	(5)	91.37	44.07	--
Co.060 (Al)	34 (M3)	15.6	15.8	87.45	47.08	80.89	43.42	7.50
Co.041 (Si)	35 (M3)	26.0	24.23	87.48	49.26	80.63	31.75	7.83
Co.057 (Si)	28 (M4)	15.8	14.64	98.85	55.78	82.94	36.71	16.10
Co.032 (Al)	36 (M3)	15.9	14.66	78.22	43.34	78.55	36.02	9.81
Co.045 (Si)	37 (M3)	15.9	15.67	95.67	53.59	68.84	22.06	28.04
Co.061 (Si)	29 (M4)	45 4	10	--	--	(7)	(7)	--
Co.011 (Si)	30 (M4)	15.9	15.82	83.99	40.60	54.04	13.72	35 66
Co.003 (Al)	50%							
	Solids	135	130	78.93	39.94	73.02	36.97	7.49
CAL.12 (Al)	31 (M4)	15.9	11.86	72.75	38.67	72.85	40.91	0
CAL.11 (Al)	32 (M4)	15 9	17.87	71.92	38.83	69.91	36.68	2.8
Co.058 (Al)	38 (M3)	15.9	15.29	85.69	45.95	78.99	42 90	7.82
Co.064 (Al)	39 (M3)	15.9	14.86	83.74	44.86	70.37	35.17	16.0

(5) Insufficient feed sample

(6) Wax coated

(7) Lost catalyst

Table 8
(Continued)

SBCR CATALYST EXTRACTIONS

Catalyst No. (Support)	Run No.	Charge		Charge		Recovered		Reduction in Particle Size, %
		(H ₂ Reduced) wt, gm	(Oxidized) wt, gm	Particle Size, mvd, microns	Particle Size at 10% microns	Particle Size, mvd, microns	Particle Size at 10% microns	
Co.063 (Al)	40 (M3)	15.0	12.02	88.99	48.36	80.70	44.32	9.32
Co.062 (Al)	41 (M3)	15.0	14.48	82.85	44.80	72.90	38.55	12.0
Co.065 (Al)	42 (M3)	15.9	17.24	83.08	44.17	71.81	37.63	13.6
CoW.12 (Si)	43 (M3)	9.1	9.44	(5)	(5)	105.95	49.99	--
CoW.11 (Al)	44 (M3)	15.6	15.24	80.32	42.03	66.93	34.40	16.7
CAL.13 (Al)	33 (M4)	15.9	14.45 (8)	80.60	43.53	104.15	59.24	--
Fe.01 (Si)	45 (M3)	15.9	15.96	84.91	46.55	78.01	39.01	8.1
CoW.05	46 (M3)	15.7	14.14	79.45	42.54	76.03	39.88	4.3
CAL.13 (Al)	35 (M4)	25.0	27.0	80.66	43.53	74.18	36.16	8.0
Co.070 (Al)	47 (M3)	15.6	17.0	85.64	45.59	78.41	40.91	8.4

(5) Insufficient feed sample.

(8) Catalyst was rinsed with solvent only,
not Soxhlet extracted.

Table 9

SUMMARY OF M4 SBCR CALSICAT CATALYST AGING RUN

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₅ -18, %	Comments
												XCH ₄	XC ₂	XC ₃ +	XC ₄			C ₃	C ₄		
33	CAL.13	15.9	1	23	39	241	450	2.0	20	28.1	1.28	6.4	1.4	90.9	1.29	0.81	0.85	3.64	2.15	23.8	
33	CAL.13	15.9	2	47	63	240	450	2.0	20	25.4	1.21	6.7	1.3	90.8	1.17	0.81	--	3.80	2.45	--	
33	CAL.13	15.9	3	71	87	240	450	2.0	20	25.7	1.18	6.8	1.3	90.8	1.14	0.80	--	3.80	2.25	--	
33	CAL.13	15.9	4	95	111	240	450	2.0	20	25.1	1.15	6.7	1.4	90.6	1.24	0.80	--	4.33	2.55	--	
33	CAL.13	15.9	5	119	135	238	450	2.0	20	22.4	1.02	5.7	1.4	91.8	1.14	0.80	--	4.25	2.50	--	
33	CAL.13	15.9	6	143	159	243	450	2.0	20	27.4	1.25	7.9	1.7	89.0	1.40	0.79	--	3.54	2.13	--	
33	CAL.13	15.9	7	162	178	240	450	2.0	20	23.8	1.09	6.4	1.5	91.0	1.13	0.80	--	4.88	2.55	--	
33	CAL.13	15.9	8	186	203	240	450	2.0	20	22.5	1.03	6.3	1.6	91.1	1.07	0.79	--	4.50	2.60	--	G.C. Calib
33	CAL.13	15.9	9	210	231	241	450	2.0	20	23.2	1.06	6.7	1.6	90.5	1.12	0.81	0.86	4.22	2.45	25.2	
33	CAL.13	15.9	10	234	255	240	450	2.0	20	21.9	1.00	6.4	1.6	90.9	1.05	0.79	--	4.50	2.78	--	
33	CAL.13	15.9	11	262	279	240	450	2.0	20	21.9	1.00	6.3	1.6	91.1	1.02	0.80	--	4.37	2.50	--	
33	CAL.13	15.9	12	282	303	240	450	2.0	20	21.4	0.98	6.1	1.5	91.4	1.01	0.80	--	4.25	2.78	--	
33	CAL.13	15.9	13	306	327	240	450	2.0	20	20.1	0.92	5.9	1.6	91.5	1.05	0.80	--	4.71	2.56	--	
33	CAL.13	15.9	14	331	351	240	450	2.0	20	20.3	0.93	6.0	1.7	91.1	1.12	0.79	--	4.13	2.67	--	
33	CAL.13	15.9	15	360	373	240	450	2.0	20	18.5	0.85	7.2	1.5	90.3	0.98	0.80	--	4.20	3.00	--	G.C. Calib
33	CAL.13	15.9	16	385	398	240	450	2.0	20	19.8	0.91	6.8	1.4	90.8	1.02	0.79	0.85	4.71	2.40	24.5	
33	CAL.13	15.9	17	402	423	240	450	2.0	20	18.4	0.84	7.5	1.6	89.9	1.09	0.78	--	4.00	2.50	--	
33	CAL.13	15.9	18	428	447	239	450	2.0	20	17.2	0.78	7.1	1.6	90.3	1.06	0.78	--	4.43	2.88	--	
33	CAL.13	15.9	19	510	519	241	450	2.0	20	15.6	0.71	6.9	1.5	90.6	1.11	0.78	--	4.67	2.63	--	Down 48hr
33	CAL.13	15.9	20	522	543	241	450	2.0	20	14.5	0.66	6.8	1.2	91.1	0.88	0.77	--	4.50	3.00	--	
33	CAL.13	15.9	21	546	567	240	450	2.0	20	13.9	0.64	6.9	1.2	91.1	0.76	0.77	0.88	5.40	3.00	26.6	
33	CAL.13	15.9	22	570	591	240	450	2.0	20	13.6	0.62	6.9	1.5	90.7	0.98	0.77	--	5.40	3.00	--	
33	CAL.13	15.9	23	596	614	240	450	2.0	20	14.1	0.64	7.0	1.5	90.6	0.95	0.77	--	4.50	3.00	--	
33	CAL.13	15.9	24	617	638	240	450	2.0	20	13.5	0.62	7.0	1.5	90.6	0.87	0.77	--	5.40	2.86	--	
33	CAL.13	15.9	25	641	662	240	450	2.0	20	13.1	0.60	7.1	1.5	90.5	0.86	0.76	--	6.50	2.86	--	
33	CAL.13	15.9	26	665	686	240	450	2.0	20	12.8	0.59	7.3	1.4	90.6	0.73	0.76	--	5.20	2.86	--	
33	CAL.13	15.9	27	689	710	240	450	2.0	20	12.6	0.58	7.2	1.4	90.5	0.86	0.76	--	5.20	2.86	--	
33	CAL.13	15.9	28	713	734	240	450	2.0	20	12.4	0.57	7.5	1.6	90.0	1.01	0.76	0.84	5.20	2.86	25.9	
33	CAL.13	15.9	29	737	758	240	450	2.0	20	12.4	0.57	7.6	1.5	90.2	0.74	0.76	--	5.20	2.86	--	
33	CAL.13	15.9	30	761	782	241	450	2.0	20	12.3	0.56	7.9	1.6	89.6	0.82	0.76	--	5.20	3.00	--	
33	CAL.13	15.9	31	785	806	241	450	2.0	20	12.3	0.56	7.8	0.7	90.9	0.52	0.76	--	6.50	2.86	--	
33	CAL.13	15.9	32	811	830	241	450	2.0	20	12.1	0.55	7.7	1.1	90.6	0.61	0.75	--	6.50	2.86	--	
33	CAL.13	15.9	33	833	854	240	450	2.0	20	11.7	0.54	7.7	1.5	90.1	0.74	0.75	0.84	5.20	2.86	--	
33	CAL.13	15.9	34	857	878	241	450	2.0	20	11.8	0.54	8.0	0.6	91.0	0.50	0.76	--	6.50	2.86	--	
33	CAL.13	15.9	35	881	902	240	450	2.0	20	11.5	0.53	8.0	0.3	91.2	0.47	0.76	--	6.50	2.86	25.9	
33	CAL.13	15.9	36	905	926	240	450	2.0	20	11.3	0.52	8.6	1.1	89.9	0.44	0.75	0.88	6.50	3.17	--	
33	CAL.13	15.9	37	929	950	240	450	2.0	20	11.3	0.52	8.8	1.3	89.5	0.46	0.75	--	6.50	3.17	--	
33	CAL.13	15.9	38	953	974	240	450	2.0	20	11.3	0.52	9.2	1.6	88.4	0.81	0.74	--	5.00	2.71	--	
33	CAL.13	15.9	39	977	998	240	450	2.0	20	11.3	0.52	9.3	1.6	88.4	0.75	0.75	--	5.00	3.33	--	
33	CAL.13	15.9	40	1001	1022	241	450	2.0	20	10.8	0.49	10.2	0.8	88.4	0.52	0.74	--	5.00	2.86	--	
33	CAL.13	15.9	41	1031	1046	241	450	2.0	20	12.9	0.60	9.3	0.0	90.7	0.00	0.77	--	5.40	3.00	--	
33	CAL.13	15.9	42	1049	1069	240	450	2.0	20	11.2	0.52	9.4	0.6	89.6	0.37	0.75	0.86	5.50	2.86	22.4	

Table 10

SUMMARY OF M4 SBCR CALSICAT CATALYST AGING RUN

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (I).

c) Conversion and selectivities are calculated using N₂ as an internal

standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt., g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₆ -18, %	Comments
35	CAL.13	25.0	1	23	40	220	450	2.0	20	17.2	0.50	7.7	0.9	97.0	0.65	0.86	0.95	6.33	4.00	25.2	
35	CAL.13	25.0	2	51	62	212	450	2.0	20	8.87	0.26	0	1.4	97.9	0.69	0.84	0.91	6.00	3.33	--	
35	CAL.13	25.0	5	143	158	213	450	2.0	20	8.57	0.25	0	0.9	98.4	0.69	0.86	--	4.00	2.50	24.5	Repair G.C
35	CAL.13	25.0	6	162	181	213	450	2.0	20	8.36	0.24	0	5.3	94.0	0.73	0.85	--	3.67	2.25	--	
35	CAL.13	25.0	7	196	205	212	450	2.0	20	8.19	0.24	0	7.3	92.2	0.53	0.81	--	3.33	2.00	--	
35	CAL.13	25.0	8	228	230	212	450	2.0	20	7.49	0.22	0	6.2	93.2	0.66	0.81	--	3.33	2.25	--	
35	CAL.13	25.0	9	237	254	212	450	2.0	20	7.39	0.21	0	4.5	94.9	0.69	0.82	--	--	--	--	
35	CAL.13	25.0	10	263	275	213	450	2.0	20	8.06	0.23	0	1.6	97.7	0.68	0.85	--	--	--	--	
35	CAL.13	25.0	11	285	302	212	450	2.0	20	7.71	0.22	0	2.7	96.5	0.76	0.84	--	--	--	--	
35	CAL.13	25.0	12	309	326	213	450	2.0	20	7.71	0.22	0	3.0	96.1	0.85	0.85	0.91	--	--	24.5	
35	CAL.13	25.0	13	333	350	213	450	2.0	20	7.51	0.22	0	2.7	96.4	0.92	0.85	--	--	--	--	
35	CAL.13	25.0	14	357	374	212	450	2.0	20	7.05	0.21	0	1.5	97.4	1.13	0.84	--	--	--	--	
35	CAL.13	25.0	15	381	398	212	450	2.0	20	8.07	0.23	0	1.3	98.3	0.42	0.86	--	--	--	--	
35	CAL.13	25.0	16	405	422	213	450	2.0	20	7.85	0.23	0	0.8	98.8	0.39	0.85	--	--	--	--	
35	CAL.13	25.0	17	429	446	212	450	2.0	20	7.38	0.22	0	1.3	98.1	0.62	0.86	--	--	--	--	
35	CAL.13	25.0	18	453	470	213	450	2.0	20	7.35	0.22	0	1.9	97.4	0.67	0.86	0.92	--	--	--	
35	CAL.13	25.0	19	477	494	213	450	2.0	20	7.61	0.22	0	2.1	97.2	0.68	0.89	--	--	4.80	--	
35	CAL.13	25.0	20	501	518	213	450	2.0	20	7.57	0.22	0	0.7	98.6	0.70	0.93	--	--	1.50	--	
35	CAL.13	25.0	21	519	524	213	450	2.0	20	7.41	0.22	0	0.7	98.7	0.74	0.94	--	--	--	--	

Figure 1

AGING RUN SBCR M4 RUN33

Calsicat Catalyst No. CAL.13, 15.9 gm.

Figure 2

AGING RUN SBCR M4 RUN33

Calsicat Catalyst No. CAL.13, 15.9 gm.

Figure 3

AGING RUN SBCR M4 RUN33

Calsicat Catalyst No. CAL.13, 15.9 gm.

Figure 4

AGING RUN SBCR M4 RUN35

Calsicat Catalyst No. CAL.13, 25.0 gm.

Time - Hours into Run

Figure 5

AGING RUN SBGR M4 RUN35

Calsicat Catalyst No. CAL.13, 25.0 gm.

Time - Hours into Run

APPENDIX A

Co CATALYST FORMULATIONS

Catalyst Prep #	Co.066	Date Tech	May-15-95	Amount	200.0 g
Compound		Co	Ru	Fe	Al ₂ O ₃
(%wt)		15	0.5	5	

Support	y-Alumina VISTA B	Amount	159.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	147.97 g
Metal	Ruthenium Nitrosyl nitrate	Amount	3.73 g
Promotor	Iron (III) Nitrate	Amount	72.31 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE

Preparation	X	Incipient Wetness	Wet Impregnation
		Ion Exchange	Other
Notes	Incipient wetness: aqueous solution of Co, Fe, Ru Dry catalyst precursor in an oven 115°C / 5 hrs with stirring		
Calcination	Temperature	300°C	Time 10 hrs
Notes	After drying, 60 g of catalyst are NOT to be calcined!!		

Co.066:

15 wt% Co
5.0 wt% Fe
0.5 wt% Ru
 γ -alumina

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$], Fe (III) nitrate and Ru nitrosil nitrate using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Co, Fe and Ru.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst	Co.067	Date	May-15-95	Amount	200.0 g
Prep #		Tech			
Compound		Co	Pd	Al2O3	
(% wt)		20	2		

PROCEDURE

Co.067:

20 wt% Co
2.0 wt% Pd
 γ -alumina

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] and Pd (II) nitrate using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Co and Pd.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	Co.068	Date Tech	May-24-95	Amount	200.0 g
Compound (%wt)		Co	Pd		Al ₂ O ₃
		20	1		

Support	y-Alumina VISTA B	Amount	158.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	197.29 g
Metal	Palladium (II) Nitrate	Amount	5.01 g
Promotor		Amount	
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution of Co, Pd Dry catalyst precursor in an oven 115°C / 5 hrs with stirring		
Calcination	Temperature	300°C	Time 10 hrs
Notes	After drying, 60 g of catalyst are NOT to be calcined!!		

Co.068:

20 wt% Co
1.0 wt% Pd
 γ -alumina

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Co nitrate $[\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}]$ and Pd (II) nitrate using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Co and Pd.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	Co.069	Date Tech	May-24-95	Amount	200.0 g
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Compound (%wt)	Co	Ru	Al ₂ O ₃
	20	2	

Support	y-Alumina VISTA B	Amount	156.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	197.29 g
Metal	Ruthenium Nitrosylnitrate	Amount	14.91 g
Promotor		Amount	
Promotor		Amount	
Promotor		Amount	

PROCEDURE

Preparation	X	Incipient Wetness	Wet Impregnation
		Ion Exchange	Other

Notes Incipient wetness: aqueous solution of Co, Fe, Ru
Dry catalyst precursor in an oven 115°C / 5 hrs with stirring

Calcination Temperature 300°C Time 10 hrs

Notes After drying, 60 g of catalyst are NOT to be calcined!!

Co.069:

20 wt% Co
2.0 wt% Ru
 γ -alumina

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] and Ru nitrosil nitrate using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Co and Ru.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	Co.070	Date Tech	Jun-08-95	Amount	200.0 g
Compound (%wt)	Co 13				Al2O3

Support	y-Alumina VISTA B	Amount	174.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	128.24 g
Metal		Amount	
Promotor		Amount	
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution of Co, 60% of loading in 1st step Dry catalyst precursor in an oven 115°C / 12 hrs with stirring Incipient wetness: aqueous solution of Co, 40% of loading in 2nd step Dry catalyst precursor in an oven 115°C / 12 hrs with stirring		
Calcination	Temperature	300°C	Time 2 hrs
Notes	After drying, 60 g of catalyst are NOT to be calcined!!		

Co.070:

13 wt% Co
 γ -alumina

Non-promoted catalyst similar to Co.005, with 13% Co.

Preparation Procedure:

Calcine the γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support in 2 steps with an aqueous solution of Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$], using an appropriate quantity to get incipient wetness (ca. 1.2 ml/g) with 60% of the desired loading of Co in the first step.

Dry in air at 115°C for 12 hours and calcine in air at 300°C for 2 hours (heating rate of ca. 1°C/min to 300°C).

In the second step, impregnate the remaining 40% of the Co. Repeat the drying and calcination procedures.

Reduction Procedure before Reaction:

Reduce the catalyst in a pure hydrogen flow of 3000 cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst Prep #	CoW.13	Date Tech	Jun-08-95	Amount	200.0 g
Compound (%wt)		Co	Ru	Fe	Al ₂ O ₃
		10	0.5	10	

Support	y-Alumina VISTA B	Amount	159.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Cobalt Nitrate	Amount	98.64 g
Metal	Ruthenium Nitrosyl nitrate	Amount	3.73 g
Promotor	Iron (III) Nitrate	Amount	144.63 g
Promotor		Amount	
Promotor		Amount	

PROCEDURE

Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution of Co, Fe, Ru Dry catalyst precursor in an oven 115°C / 5 hrs with stirring		

Calcination Temperature 300°C Time 10 hrs

Notes After drying, 60 g of catalyst are NOT to be calcined!!

CoW.13 10 wt% Fe
 10 wt% Co
 0.5 wt% Ru
 γ -alumina

Ru promoted cobalt/iron impregnated on calcined γ -alumina similar to CoW.10 (2nd batch).

Preparation Procedure

Calcine γ -alumina at 500°C for 10 hrs. Use Vista B alumina. Presieve to >38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of Fe nitrate [$\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$], Co nitrate [$\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$] and Ru nitrosylnitrate [$\text{Ru}(\text{NO})(\text{NO}_3)_3 \cdot 2\text{H}_2\text{O}$] using appropriate quantities to get incipient wetness (ca. 1.2 ml/g) with the desired loading of Fe, Co, and Ru.

Dry the catalyst precursor in an oven for 5 hrs at 115°C with moderate stirring.

Calcine the dried catalyst in air by raising its temperature at a heating rate of ca. 1°C/min to 300°C and holding for 10 hrs.

Reduction Procedure before Reaction:

Reduce the catalyst in pure hydrogen flow of 3000cc/g/hr by heating at 1°C/min to 350°C and holding for 10 hrs.

Catalyst	Fe.01	Date	May-05-95	Amount	200.0 g
Prep #		Tech			
Compound		Fe	Cu		SiO ₂
(%wt)		30	1.5		

Support	Silica Davison Grade 952	Amount	137.00 g
Particle Size	400 - 0 mesh	Treatment	500°C / 10 hrs
Cobalt	Iron (III) Nitrate	Amount	433.88 g
Metal	Copper (II) Nitrate	Amount	11.40 g
Promotor		Amount	
Promotor		Amount	
Promotor		Amount	

PROCEDURE			
Preparation	X	Incipient Wetness Ion Exchange	Wet Impregnation Other
Notes	Incipient wetness: aqueous solution of Fe + Cu Dry catalyst precursor in an oven 110°C / 16 hrs		
Calcination	Temperature	<u>500°C</u>	Time <u>24 hrs</u>
Notes			

Fe.01 **30 wt% Fe**
 1.5 wt% Cu
 Silica

Preparation Procedure of Fe-Cu/Silica

Calcine silica at 500°C for 10 hrs. Use Davison Grade 952 silica. Presieve to > 38 microns (400-0 mesh).

Impregnate the support with an aqueous solution of $\text{Fe}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$ and $\text{Cu}(\text{NO}_3)_2 \cdot 3\text{H}_2\text{O}$ using appropriate quantities to yield 30 wt% Fe and 1.5% Cu by weight and to get incipient wetness (ca. 1.2 ml/g).

Dry the catalyst precursor in an oven for 16 hours at 110°C.

The dried catalyst is then calcined in air by raising its temperature at a heating rate of ca. 1°C/min to 500°C and holding for 24 hours.

Reduction Procedure before Reaction:

A mixture of H_2O and H_2 is used for reduction to Fe_3O_4 . Raise the temperature of the bed 10C/min to 400°C with the feed being $\text{H}_2\text{O}/\text{H}_2 > 0.09$ and maintain these conditions for 48 hrs

APPENDIX B

FIXED BED REACTION DATA

Co.025 - Run #X

Co wt%	NM wt %	Promotor wt%		Support
20		Zr 8.50		SiO ₂

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.200 g

WHSV = 12.86 1/hr

time on stream = 23.5 hrs

CO₂ (% of CO) =
O/P = 0

0.00

CO conversion (%)	2.0
rate (g CH ₂ /g cat/hr)	0.11
alpha	0.61
C1 (wt%)	26.8
C2 - C4 (wt%)	29.7
C5 - C12 (wt%)	41.1
C13 + (wt%)	2.4

Performance of Co.025

Dates: 05/26/95 - 01/00/00 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	2.5	5.5	8.5	11.5	14.5	17.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	30.91	26.33	27.04	32.13	28.69	29.06
C2	7.54	6.25	6.28	7.34	6.51	6.55
C3	16.68	13.41	13.25	1.16	13.20	13.14
C4	16.59	13.32	12.97	14.60	12.74	12.64
C5	15.96	12.80	12.37	13.72	12.04	11.87
C6	12.31	8.91	9.51	10.37	8.89	8.99
C7	0.00	6.40	6.24	6.98	6.11	5.95
C8	0.00	4.24	4.14	4.64	3.99	4.02
C9	0.00	2.83	2.78	3.03	2.68	2.71
C10	0.00	1.97	1.98	2.18	1.88	1.76
C11	0.00	1.17	1.14	1.24	1.10	1.15
C12	0.00	0.78	0.75	0.89	0.72	0.66
C13	0.00	0.58	0.53	0.53	0.47	0.46
C14	0.00	0.48	0.43	0.46	0.37	0.42
C15	0.00	0.34	0.35	0.42	0.34	0.33
alpha chain growth probability	1.00	0.60	0.60	0.60	0.59	0.60

C1 - C50 estimated total product distribution, weight %

C1	0.0	26.0	26.8	31.8	28.5	28.8
C2 - C4	0.0	32.5	32.2	22.9	32.2	32.0
C5 - C12	1.9	39.5	39.2	43.3	37.7	37.5
C13 - C50	98.0	2.1	1.8	2.0	1.6	1.8

CO conversion, %	2758.2	2.6	2.5	2.1	2.3	2.2
rate, g CH ₂ /g cat/hr	155.15	0.14	0.14	0.12	0.13	0.13
CO ₂ formation, %						

Performance of Co.025

Dates: 05/26/95 - 01/00/00 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	20.5	23.5	26.5	29.5	32.5	35.5
reaction temperature, °C	220	220	220	220	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	29.00	26.98	30.47	30.26	61.53	42.84
C2	6.53	6.18	6.98	6.92	9.66	9.80
C3	13.11	11.81	12.94	12.85	14.80	11.72
C4	12.63	11.88	12.07	11.83	7.10	6.24
C5	11.84	11.84	11.12	11.06	3.74	3.88
C6	9.14	9.20	8.70	8.67	0.35	0.51
C7	5.85	6.53	5.65	5.69	0.89	7.62
C8	3.95	4.70	3.73	3.81	0.56	5.01
C9	2.62	3.33	2.51	2.82	0.38	3.45
C10	1.84	2.54	1.77	1.75	0.24	2.46
C11	1.13	1.83	1.20	1.32	0.17	1.64
C12	0.63	1.24	0.81	0.90	0.11	1.37
C13	0.54	0.83	0.67	0.69	0.12	0.08
C14	0.34	0.55	0.62	0.60	0.10	1.04
C15	0.32	0.33	0.48	0.50	0.14	1.26
alpha chain growth probability	0.59	0.61	0.62	0.62	0.54	0.67

C1 - C50 estimated total product distribution, weight %

C1	29.0	26.8	29.8	29.8	61.2	41.5
C2 - C4	32.2	29.7	31.3	31.1	31.4	26.9
C5 - C12	37.4	41.1	36.1	36.5	6.9	26.7
C13 - C50	1.4	2.4	2.7	2.6	0.4	4.9

CO conversion, %	2.1	2.0	1.5	1.6	6.1	3.9
rate, g CH ₂ /g cat/hr	0.12	0.11	0.09	0.09	0.34	0.22
CO ₂ formation, %						

Performance of Co.025 Dates: 05/26/95 - 01/00/00 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	38.5	41.5	44.5	48.8	51.8	54.8
reaction temperature, °C	280	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	50.10	46.05	54.33	45.49	45.35	47.32
C2	13.60	13.78	17.39	15.16	15.65	16.53
C3	14.30	13.30	15.73	13.10	13.06	1.36
C4	8.00	7.67	9.04	7.71	7.59	8.14
C5	5.43	5.39	0.52	5.47	5.62	6.29
C6	1.32	3.32	1.83	1.25	1.32	1.31
C7	1.98	2.19	0.22	2.26	2.66	3.13
C8	1.33	1.48	0.15	1.84	1.86	2.23
C9	0.93	1.04	0.11	1.21	1.29	1.67
C10	0.68	0.82	0.09	1.02	1.27	1.35
C11	0.49	0.67	0.06	0.75	0.79	1.07
C12	0.45	0.58	0.05	0.58	0.63	0.85
C13	0.32	0.02	0.04	0.47	0.56	0.71
C14	0.33	0.45	0.05	0.44	0.60	0.67
C15	0.32	0.43	0.05	0.52	0.70	0.75
alpha chain growth probability	0.60	0.62	0.51	0.70	0.64	0.66

C1 - C50 estimated total product distribution, weight %

C1	49.6	46.3	54.3	46.1	44.7	49.5
C2 - C4	35.5	34.9	42.1	36.5	35.8	27.2
C5 - C12	13.5	16.8	3.4	15.0	16.8	20.0
C13 - C50	1.4	2.0	0.2	2.4	2.7	3.3

CO conversion, %	2.0	1.6	1.1	1.0	0.9	0.7
rate, g CH ₂ /g cat/hr	0.11	0.09	0.06	0.06	0.05	0.04
CO ₂ formation, %						

Performance of Co.025
 Dates: 05/26/95 - 01/00/00 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	57.8	60.8	63.8	66.8	69.8	0.0
reaction temperature, °C	220	220	220	220	220	0
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	90.0	90.0	90.0	0.0

C1 - C15 product distribution, weight %

C1	26.12	30.14	29.39	30.26	31.79	0.00
C2	9.68	11.15	6.02	6.05	6.22	0.00
C3	8.32	9.61	13.04	13.05	13.34	0.00
C4	7.35	8.67	12.67	12.66	12.62	0.00
C5	7.28	8.42	11.54	11.38	11.45	0.00
C6	4.82	1.13	8.57	8.55	8.26	0.00
C7	5.00	5.80	5.33	5.21	5.11	0.00
C8	4.06	4.66	3.61	3.40	3.30	0.00
C9	3.55	4.10	2.38	2.24	2.18	0.00
C10	2.92	3.18	1.89	1.57	1.43	0.00
C11	2.71	3.33	1.20	0.97	1.24	0.00
C12	2.54	2.55	0.63	0.67	0.59	0.00
C13	1.88	1.84	0.54	0.47	0.43	0.00
C14	1.69	1.64	0.48	0.39	0.35	0.00
C15	1.71	1.73	0.51	0.39	0.35	0.00
alpha chain growth probability	0.73	0.79	0.60	0.62	0.59	0.00

C1 - C50 estimated total product distribution, weight %

C1	27.5	27.9	29.6	30.8	32.0	0.0
C2 - C4	26.7	27.2	31.9	32.3	32.4	0.0
C5 - C12	35.7	31.0	36.4	35.1	34.2	0.0
C13 - C50	10.0	13.9	2.1	1.8	1.5	0.0

CO conversion, %	0.3	0.3	2.2	2.1	2.1	0.0
rate, g CH ₂ /g cat/hr	0.02	0.02	0.12	0.12	0.12	0.00
CO ₂ formation, %						

CO Hydrogenation on Co.025 - ASF Product Distribution

CO Hydrogenation on Co.025

CO Hydrogenation on Co.025

Co.053 - Run #12

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.210 g

WHSV = 12.24 1/hr

time on stream = 3.5 hrs

CO₂ (g/g cat/hr) = 0.029CO₂ (% of CO) = 0.2

O/P = 0.98

CO conversion (%)	8.1
rate (g CH ₂ /g cat/hr)	0.43
alpha	0.60
C1 (wt%)	26.6
C2 - C4 (wt%)	29.2
C5 - C12 (wt%)	42.9
C13 + (wt%)	1.3

Performance of Co.053

Dates: 03/23/95 - 03/24/95 Run #12

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.2 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	18.5	21.5	24.5	30.5
reaction temperature, °C	220	220	220	220	220	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	26.33	26.22	25.93	27.04	26.95	61.30
C2	5.02	4.51	4.32	4.48	4.74	8.61
C3	12.10	11.86	10.84	11.41	11.33	12.82
C4	12.27	12.38	11.02	11.59	11.62	7.57
C5	11.46	11.86	10.49	11.27	11.10	4.11
C6	8.89	9.29	8.80	8.85	8.83	1.90
C7	7.23	7.50	6.70	7.18	7.08	1.23
C8	5.08	5.34	4.85	5.15	5.13	0.83
C9	3.65	3.83	3.60	3.75	3.74	0.57
C10	2.60	2.59	2.63	2.64	2.68	0.32
C11	2.05	2.01	2.10	2.00	2.00	0.25
C12	1.36	1.22	1.53	1.38	1.43	0.16
C13	0.93	0.79	2.75	1.09	1.12	0.11
C14	0.70	0.42	3.73	1.43	1.21	0.10
C15	0.33	0.19	0.71	0.73	1.03	0.11
alpha chain growth probability	0.63	0.60	0.68	0.68	0.70	0.55

C1 - C50 estimated total product distribution, weight %

C1	26.5	26.6	26.4	26.3	25.4	60.4
C2 - C4	29.5	29.2	26.6	26.7	26.1	28.6
C5 - C12	41.8	42.9	42.1	42.1	41.7	10.2
C13 - C50	2.2	1.3	4.9	4.8	6.8	0.7

CO conversion, %	8.5	8.1	7.5	7.2	7.5	25.0
rate, g CH ₂ /g cat/hr	0.45	0.43	0.40	0.38	0.40	1.34
CO ₂ formation, %	0.2	0.2	0.1	0.1	0.2	4.7

Performance of Co.053

Dates: 03/23/95 - 03/24/95 Run #12

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.2 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	33.5	36.5	39.5	42.5	45.5
reaction temperature, °C	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	49.90	46.39	44.25	42.94	41.67
C2	9.11	10.00	10.75	11.46	11.89
C3	15.30	14.80	14.53	14.45	14.25
C4	9.01	9.02	9.05	9.07	8.95
C5	6.13	6.49	6.75	6.84	6.83
C6	2.93	3.94	4.30	4.52	4.66
C7	2.47	2.84	3.14	3.22	3.33
C8	1.67	1.89	2.09	2.33	2.30
C9	1.08	1.30	1.43	1.49	1.58
C10	0.72	0.90	1.03	1.06	1.19
C11	0.50	0.68	0.80	0.76	0.84
C12	0.37	0.44	0.49	0.54	0.61
C13	0.30	0.34	0.41	0.43	0.52
C14	0.25	0.40	0.47	0.48	0.65
C15	0.26	0.58	0.50	0.42	0.74
alpha chain growth probability	0.63	0.68	0.67	0.66	0.69

C1 - C50 estimated total product distribution, weight %

C1	48.9	44.2	42.6	41.7	39.4
C2 - C4	32.7	32.2	33.0	33.9	33.1
C5 - C12	16.7	19.8	21.1	21.6	22.7
C13 - C50	1.7	3.8	3.3	2.7	4.8

CO conversion, %	11.8	8.9	7.0	5.9	5.3
rate, g CH ₂ /g cat/hr	0.63	0.48	0.38	0.32	0.28
CO ₂ formation, %	1.2	0.9	0.6	0.5	0.4

Time-on-Stream Plot for C0.053 - Run #12

Schulz-Flory Plot for Co.053 - Run #12

Time on Stream (hrs)

hrs.

Co.053 - Run #12a

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 280 °C

H₂/CO = 2

weight of catalyst = 0.210 g

WHSV = 12.24 1/hr

time on stream = 45.5 hrs

CO₂ (g/g cat/hr) = 0.083CO₂ (% of CO) = 0.4

O/P = 9.41

CO conversion (%)	5.3
rate (g CH ₂ /g cat/hr)	0.28
alpha	0.69
C1 (wt%)	39.4
C2 - C4 (wt%)	33.1
C5 - C12 (wt%)	22.7
C13 + (wt%)	4.8

Time-on-Stream Plot for C0.053 - Run #12a

Schulz-Flory Plot for Co.053 - Run #12a
Time on Stream (hrs)

hrs.

Co.053 - Run #12b

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.210 g

WHSV = 12.24 1/hr

time on stream = 3.5 hrs

CO₂ (g/g cat/hr) = 0.021CO₂ (% of CO) = 0.1

O/P = 5.07

CO conversion (%)	1.4
rate (g CH ₂ /g cat/hr)	0.08
alpha	0.78
C1 (wt%)	20.0
C2 - C4 (wt%)	21.8
C5 - C12 (wt%)	38.8
C13 + (wt%)	19.5

Performance of Co.053

Dates: 03/29/95 - 03/30/95 Run #12b

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.2 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	0.5	3.5	0.5	6.5	9.5	12.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	23.55	24.31	32.10	31.31	31.24	30.83
C2	6.72	6.77	5.47	5.26	5.24	5.17
C3	9.97	9.94	13.05	12.13	12.17	12.12
C4	9.69	9.74	13.48	12.14	12.15	12.09
C5	9.81	9.52	10.70	11.16	11.22	11.30
C6	7.26	7.91	7.82	8.12	8.23	8.47
C7	6.74	6.44	6.09	6.47	6.48	6.54
C8	5.34	5.16	4.09	4.37	4.33	4.38
C9	4.36	4.18	2.78	3.00	2.97	2.96
C10	3.55	3.43	1.83	1.89	1.88	1.95
C11	2.84	2.82	1.37	1.46	1.44	1.47
C12	2.54	2.28	0.72	0.95	0.91	0.93
C13	2.39	2.10	0.35	0.72	0.58	0.59
C14	2.72	2.52	0.12	0.72	0.55	0.56
C15	2.51	2.87	0.04	0.30	0.62	0.64
alpha chain growth probability	0.77	0.78	0.52	0.62	0.66	0.66

C1 - C50 estimated total product distribution, weight %

C1	20.2	20.0	32.6	31.2	30.0	29.6
C2 - C4	22.6	21.8	32.5	29.4	28.4	28.2
C5 - C12	40.0	38.8	34.6	37.4	37.6	38.1
C13 - C50	17.3	19.5	0.3	2.0	4.0	4.1

CO conversion, %	1.4	1.4	9.0	8.8	8.8	8.5
rate, g CH ₂ /g cat/hr	0.07	0.08	0.48	0.47	0.47	0.45
CO ₂ formation, %	0.1	0.1	0.2	0.2	0.2	0.2

Performance of Co.053

Dates: 03/29/95 - 03/30/95 Run #12b

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.2 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	15.5	18.5	21.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	30.84	30.69	30.26
C2	5.15	5.11	5.40
C3	12.12	12.13	12.19
C4	12.10	12.10	12.25
C5	11.23	11.30	11.23
C6	8.40	8.50	8.47
C7	6.52	6.57	6.49
C8	4.39	4.42	4.41
C9	3.02	3.02	3.05
C10	1.97	1.99	2.08
C11	1.48	1.52	1.55
C12	0.92	0.87	0.88
C13	0.68	0.63	0.60
C14	0.58	0.54	0.58
C15	0.62	0.60	0.55
alpha chain growth probability	0.66	0.66	0.65

C1 - C50 estimated total product distribution, weight %

C1	29.7	29.6	29.3
C2 - C4	28.2	28.3	28.9
C5 - C12	38.1	38.3	38.2
C13 - C50	4.0	3.9	3.6

CO conversion, %	8.4	8.4	8.3
rate, g CH ₂ /g cat/hr	0.45	0.45	0.44
CO ₂ formation, %	0.2	0.2	0.2

Co.053 - Run #13

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.210 g

WHSV = 12.24 1/hr

time on stream = 21.5 hrs

CO₂ (g/g cat/hr) = 0.037CO₂ (% of CO) = 0.2

O/P = 0.88

CO conversion (%)	8.3
rate (g CH ₂ /g cat/hr)	0.44
alpha	0.65
C1 (wt%)	29.3
C2 - C4 (wt%)	28.9
C5 - C12 (wt%)	38.2
C13 + (wt%)	3.6

* calcined and reduced insitu after run 12

Time-on-Stream Plot for C0.053 - Run #13

Schulz-Flory Plot for Co.053 - Run #13
Time on Stream (hrs)

hrs.

Co.053 - Run #14

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.201 g

WHSV = 12.78 1/hr

time on stream = 19.5 hrs

CO₂ (g/g cat/hr) = 0.025CO₂ (% of CO) = 0.1

O/P = 0.85

CO conversion (%)	6.7
rate (g CH ₂ /g cat/hr)	0.37
alpha	0.74
C1 (wt%)	24.8
C2 - C4 (wt%)	24.4
C5 - C12 (wt%)	37.3
C13 + (wt%)	13.6

* Catalyst calcined (24 hr, 300 °C) and reduced (10 hr, 350 °C)
after reaction at EI

Performance of Co.053

Dates: 04/17/95 - 04/18/95 Run #14

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	1.5	4.5	7.5	10.5	13.5	16.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	29.35	28.82	29.92	29.95	29.06	29.68
C2	4.95	5.17	5.29	5.11	4.88	4.96
C3	12.23	12.16	12.51	12.45	12.07	12.24
C4	12.13	12.12	12.53	12.29	11.90	12.01
C5	11.23	11.15	11.49	11.47	11.16	11.19
C6	8.04	8.15	8.52	8.30	8.10	8.01
C7	6.42	6.33	6.54	6.46	6.38	6.38
C8	4.26	4.23	4.38	4.34	4.26	4.25
C9	2.90	2.89	2.97	2.79	2.94	2.90
C10	1.85	1.88	2.09	2.30	2.10	1.89
C11	1.43	1.44	1.62	1.57	1.60	1.38
C12	1.10	1.19	0.87	0.90	1.05	0.98
C13	1.75	2.10	0.54	0.62	0.94	0.87
C14	1.26	1.24	0.39	0.60	2.42	2.21
C15	1.11	1.13	0.33	0.84	1.16	1.03
alpha chain growth probability	0.70	0.70	0.62	0.68	0.70	0.69

C1 - C50 estimated total product distribution, weight %

C1	27.4	27.0	29.6	28.2	27.1	27.9
C2 - C4	27.4	27.5	30.0	28.1	26.9	27.5
C5 - C12	38.0	38.1	38.3	38.3	38.4	38.0
C13 - C50	7.2	7.3	2.2	5.4	7.5	6.7

CO conversion, %	6.8	6.4	5.7	5.9	6.1	6.0
rate, g CH ₂ /g cat/hr	0.38	0.36	0.32	0.33	0.34	0.33
CO ₂ formation, %	0.1	0.1	0.1	0.1	0.2	0.1

Performance of Co.053

Dates: 04/17/95 - 04/18/95 Run #14

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	19.5
reaction temperature, °C	220
pressure, atm	1.0
flow, cc/min	90.0

C1 - C15 product distribution, weight %

C1	29.27
C2	4.88
C3	12.06
C4	11.82
C5	11.09
C6	8.20
C7	6.26
C8	4.19
C9	2.84
C10	2.02
C11	1.55
C12	0.91
C13	0.82
C14	1.93
C15	2.15
alpha chain growth probability	0.74

C1 - C50 estimated total product distribution, weight %

C1	24.8
C2 - C4	24.4
C5 - C12	37.3
C13 - C50	13.6

CO conversion, %	6.7
rate, g CH ₂ /g cat/hr	0.37
CO ₂ formation, %	0.1

Schulz-Flory Plot for Co.053 - Run #14
Time on Stream (hrs)

hrs.

Time-on-Stream Plot for Co.053 - Run #14

Co055 - Run #X

Co wt%	NM wt %	Promotor wt%		Support
20	Re 1.00	La 1.00		Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.200 g

WHSV = 12.86 1/hr

time on stream = 26.5 hrs

CO₂ (% of CO) =

O/P = 0.04

0.00

CO conversion (%)	6.1
rate (g CH ₂ /g cat/hr)	0.34
alpha	0.66
C1 (wt%)	29.7
C2 - C4 (wt%)	29.4
C5 - C12 (wt%)	37.6
C13 + (wt%)	3.3

Performance of Co055

Dates: 05/29/95 - 05/31/95 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	2.5	5.5	8.5	11.5	17.5	20.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0
C1 - C15 product distribution, weight %						
C1	27.06	28.11	27.75	27.81	29.81	29.59
C2	4.76	4.86	4.75	4.92	5.22	5.13
C3	12.36	12.33	11.85	11.71	12.35	12.05
C4	12.50	12.29	11.65	11.75	12.24	11.78
C5	12.14	11.89	11.29	10.84	11.42	10.99
C6	9.55	9.40	9.45	8.56	8.94	8.70
C7	6.64	6.41	6.11	5.80	6.12	5.80
C8	4.81	4.69	4.38	4.19	4.43	4.24
C9	3.42	3.33	3.13	2.84	3.16	3.03
C10	2.56	2.48	2.18	2.37	2.35	2.30
C11	1.72	1.80	1.87	1.61	1.69	1.64
C12	1.38	1.25	1.37	1.27	1.19	1.22
C13	0.65	0.68	1.02	0.79	0.64	0.36
C14	0.33	0.36	0.76	0.59	0.32	1.17
C15	0.14	0.13	0.54	0.47	0.12	0.47
alpha chain growth probability	0.61	0.61	0.67	0.65	0.61	0.70
C1 - C50 estimated total product distribution, weight %						
C1	27.3	28.3	27.8	28.9	30.0	28.3
C2 - C4	29.9	29.7	28.3	29.4	30.0	27.7
C5 - C12	41.4	40.5	40.2	38.9	38.5	38.2
C13 - C50	1.5	1.6	3.7	2.8	1.4	5.8
CO conversion, %	7.1	6.7	6.9	6.6	6.2	6.7
rate, g CH ₂ /g cat/hr	0.40	0.38	0.39	0.37	0.35	0.38
CO ₂ formation, %						

Performance of Co055

Dates: 05/29/95 - 05/31/95 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	23.5	26.5	32.5	35.5	38.5	41.5
reaction temperature, °C	220	220	220	220	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	29.75	29.55	32.32	31.84	51.85	37.13
C2	5.18	5.26	5.46	5.32	9.62	12.67
C3	12.07	12.15	12.80	12.45	16.93	16.00
C4	11.79	11.78	11.46	11.05	9.12	9.97
C5	10.90	10.75	10.64	9.97	5.42	7.45
C6	8.58	8.43	10.16	7.65	2.98	4.94
C7	5.72	5.71	5.06	4.75	1.37	3.07
C8	4.19	4.17	3.52	3.32	0.98	2.18
C9	2.86	3.03	2.35	2.24	0.61	1.61
C10	2.44	2.13	1.60	1.75	0.41	1.06
C11	1.75	1.82	1.20	1.39	0.29	0.69
C12	1.16	1.37	0.79	0.75	0.20	0.51
C13	0.88	0.85	0.46	0.45	0.15	0.42
C14	0.64	0.69	0.43	0.34	0.08	0.31
C15	0.49	0.50	0.34	0.49	0.00	0.23
alpha chain growth probability	0.66	0.66	0.63	0.62	0.55	0.62

C1 - C50 estimated total product distribution, weight %

C1	29.9	29.7	32.4	34.0	51.7	37.4
C2 - C4	29.2	29.4	29.8	30.8	35.6	39.0
C5 - C12	37.9	37.6	35.8	33.7	12.3	22.2
C13 - C50	3.0	3.3	1.9	1.6	0.3	1.4

CO conversion, %	6.3	6.1	5.3	5.3	15.4	6.3
rate, g CH ₂ /g cat/hr	0.35	0.34	0.30	0.30	0.86	0.36
CO ₂ formation, %						

Performance of Co055 Dates: 05/29/95 - 05/31/95 Run #X

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	47.5	50.5	53.5	56.5	59.5	62.5
reaction temperature, °C	280	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	33.68	33.08	33.66	34.02	35.43	38.66
C2	14.77	15.66	16.26	16.22	16.14	16.36
C3	15.51	15.26	15.08	14.07	13.14	13.04
C4	9.57	9.37	9.15	8.36	7.73	7.38
C5	7.15	7.11	6.58	6.16	5.90	5.46
C6	4.70	2.93	2.88	2.59	1.93	1.76
C7	3.27	3.37	3.22	3.24	2.97	2.61
C8	2.46	2.49	2.43	2.40	2.24	1.96
C9	1.75	1.93	1.70	1.77	1.82	1.30
C10	1.30	1.36	1.34	1.28	0.99	1.03
C11	0.98	1.18	0.92	0.85	0.83	0.74
C12	0.66	0.73	0.84	0.69	0.71	0.66
C13	0.49	0.59	0.61	0.69	0.74	0.43
C14	0.44	0.55	0.45	0.47	0.54	0.45
C15	0.37	0.48	0.46	0.55	0.66	0.55
alpha chain growth probability	0.64	0.66	0.68	0.68	0.67	0.66

C1 - C50 estimated total product distribution, weight %

C1	34.2	33.8	34.9	36.0	37.9	41.2
C2 - C4	40.5	41.2	42.0	40.9	39.6	39.2
C5 - C12	23.2	22.3	20.9	20.6	19.6	17.3
C13 - C50	2.1	2.7	2.3	2.4	2.8	2.3

CO conversion, %	3.3	2.1	1.3	0.9	0.7	0.7
rate, g CH ₂ /g cat/hr	0.19	0.12	0.07	0.05	0.04	0.04
CO ₂ formation, %						

CO Hydrogenation on Co.055 - ASF Product Distribution

CO Hydrogenation on Co.055

CO Hydrogenation on Co.055

Co.064 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20	Ru 0.50		Zr 8.50	Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.208 g

WHSV = 12.36 1/hr

time on stream = 24.5 hrs

CO₂ (g/g cat/hr) = 0.028CO₂ (% of CO) = 0.2

O/P = 1.58

CO conversion (%)	7.1
rate (g CH ₂ /g cat/hr)	0.38
alpha	0.64
C1 (wt%)	27.5
C2 - C4 (wt%)	28.4
C5 - C12 (wt%)	41.5
C13 + (wt%)	2.7

Time-on-Stream Plot for Co.064 - Run #1

Performance of Co.064

Dates: 04/11/95 - 04/12/95 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.4 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	3.5	21.5	24.5
reaction temperature, °C	220	220	220
pressure, atm	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	28.79	28.40	27.58
C2	5.44	3.25	4.61
C3	13.05	12.20	11.78
C4	11.30	11.80	12.14
C5	12.01	11.57	11.67
C6	9.28	9.08	8.43
C7	6.71	7.11	7.15
C8	4.67	5.03	5.13
C9	3.22	3.63	3.70
C10	2.08	2.44	2.53
C11	1.52	1.93	1.90
C12	0.90	1.19	1.25
C13	0.58	1.00	0.89
C14	0.32	0.96	0.86
C15	0.13	0.42	0.40
alpha chain growth probability	0.57	0.64	0.64

C1 - C50 estimated total product distribution, weight %

C1	29.1	28.3	27.5
C2 - C4	30.1	27.1	28.4
C5 - C12	39.8	41.8	41.5
C13 - C50	0.9	2.8	2.7

CO conversion, %	8.2	6.9	7.1
rate, g CH ₂ /g cat/hr	0.44	0.37	0.38
CO ₂ formation, %	0.2	0.2	0.2

Schulz-Flory Plot for Co.064 - Run #1
Time on Stream (hrs)

hrs.

Co.066 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
15	Ru 0.50	Fe 5.00		Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.200 g

WHSV = 12.86 1/hr

time on stream = 23.5 hrs

CO₂ (% of CO) =

O/P = 0

0.00

CO conversion (%)	1.7
rate (g CH ₂ /g cat/hr)	0.10
alpha	0.67
C1 (wt%)	27.7
C2 - C4 (wt%)	29.4
C5 - C12 (wt%)	39.1
C13 + (wt%)	3.8

Performance of Co.066

Dates: 06/06/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	2.5	5.5	8.5	11.5	14.5	17.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	21.43	26.37	26.49	26.58	26.72	27.08
C2	22.13	5.89	5.86	5.85	5.85	5.95
C3	10.43	12.30	12.08	11.78	11.76	11.79
C4	10.20	11.89	11.72	11.57	11.45	11.48
C5	9.40	11.30	11.01	11.03	10.84	10.90
C6	7.08	8.38	7.95	8.09	8.13	7.64
C7	4.81	5.71	5.65	5.71	5.59	5.78
C8	3.43	3.96	3.99	4.05	4.00	3.99
C9	2.42	2.86	2.85	2.95	2.85	2.90
C10	1.89	2.14	2.18	2.26	2.21	2.25
C11	1.34	1.58	1.59	1.59	1.58	1.52
C12	1.00	1.24	1.27	1.24	1.21	1.17
C13	0.75	0.92	0.94	0.94	0.90	0.89
C14	0.59	0.72	0.78	0.75	0.69	0.76
C15	0.60	0.69	0.74	0.76	0.70	0.67
alpha chain growth probability	0.65	0.66	0.67	0.67	0.66	0.67

C1 - C50 estimated total product distribution, weight %

C1	21.7	27.0	27.3	27.4	27.9	27.9
C2 - C4	43.2	30.8	30.6	30.1	30.3	30.1
C5 - C12	32.3	38.7	38.3	38.7	38.4	38.1
C13 - C50	2.8	3.5	3.9	3.7	3.4	3.8

CO conversion, %	2.6	2.0	1.9	1.8	1.8	1.7
rate, g CH ₂ /g cat/hr	0.14	0.11	0.11	0.10	0.10	0.10
CO ₂ formation, %						

Performance of Co.066

Dates: 06/06/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	20.5	23.5	26.5	29.5	32.5	35.5
reaction temperature, °C	220	220	220	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	29.62	26.87	28.52	52.47	40.76	37.34
C2	6.45	5.88	6.42	9.21	12.13	13.62
C3	12.35	11.38	12.43	16.57	14.97	14.67
C4	11.61	11.24	11.58	8.88	9.30	9.36
C5	10.25	10.88	10.84	5.33	6.84	7.15
C6	5.88	8.60	8.16	2.80	4.43	2.54
C7	5.41	5.71	5.39	1.43	2.86	3.35
C8	3.86	4.11	3.66	0.91	1.96	2.36
C9	2.72	2.92	2.58	0.56	1.37	1.67
C10	2.09	2.29	1.96	0.36	1.05	1.43
C11	1.53	1.62	1.29	0.27	0.73	0.88
C12	1.11	1.17	1.01	0.17	0.50	0.71
C13	0.87	0.92	0.71	0.11	0.36	0.54
C14	0.70	0.76	0.55	0.09	0.32	0.49
C15	0.64	0.74	0.56	0.06	0.23	0.38
alpha chain growth probability	0.66	0.67	0.65	0.55	0.62	0.65

C1 - C50 estimated total product distribution, weight %

C1	30.6	27.7	29.5	52.7	41.2	38.0
C2 - C4	31.4	29.4	31.4	34.8	36.8	38.4
C5 - C12	34.6	39.1	36.5	12.1	20.5	21.3
C13 - C50	3.4	3.8	2.6	0.4	1.4	2.3

CO conversion, %	1.0	1.7	1.6	8.9	3.7	2.3
rate, g CH ₂ /g cat/hr	0.06	0.10	0.09	0.50	0.21	0.13
CO ₂ formation, %						

Performance of Co.066 Dates: 06/06/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	38.5	41.5	44.5	48.8	51.8	54.8
reaction temperature, °C	280	280	280	280	280	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	36.00	34.36	32.81	31.89	30.85	19.75
C2	14.57	14.91	14.97	15.13	15.22	12.07
C3	14.57	14.30	13.95	13.81	13.46	7.69
C4	9.28	9.06	8.75	8.74	8.56	6.72
C5	6.93	6.88	6.76	6.86	6.66	6.81
C6	2.81	2.96	2.92	3.00	2.94	1.91
C7	3.40	3.43	3.46	3.52	3.47	4.37
C8	2.46	2.53	2.57	2.67	2.70	3.64
C9	1.78	1.90	1.92	1.99	1.98	3.13
C10	1.36	1.41	1.37	1.44	1.53	2.77
C11	0.95	1.02	1.05	1.15	1.19	2.48
C12	0.76	0.80	0.81	0.89	0.93	2.05
C13	0.60	0.67	0.79	0.79	0.78	1.81
C14	0.62	0.57	0.62	0.67	0.70	1.71
C15	0.49	0.56	0.65	0.73	0.89	1.99
alpha chain growth probability	0.67	0.67	0.67	0.68	0.68	0.77

C1 - C50 estimated total product distribution, weight %

C1	36.4	35.4	34.4	33.5	32.9	23.1
C2 - C4	38.8	39.4	39.5	39.6	39.7	30.9
C5 - C12	21.8	22.4	22.9	23.5	23.8	32.7
C13 - C50	3.1	2.8	3.2	3.5	3.7	13.3

CO conversion, %	1.8	1.4	1.1	1.0	0.8	0.2
rate, g CH ₂ /g cat/hr	0.10	0.08	0.06	0.05	0.05	0.01
CO ₂ formation, %						

CO Hydrogenation on Co.066 - ASF Product Distribution

CO Hydrogenation on Co.066

CO Hydrogenation on Co.066

Co.067 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20	Pd 2.00			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.200 g

WHSV = 12.87 1/hr

time on stream = 20.5 hrs

CO₂ (% of CO) =

O/P = 0

0.00

CO conversion (%)	2.2
rate (g CH ₂ /g cat/hr)	0.13
alpha	0.67
C1 (wt%)	25.0
C2 - C4 (wt%)	29.2
C5 - C12 (wt%)	41.6
C13 + (wt%)	4.2

Performance of Co.067

Dates: 06/21/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	2.5	5.5	8.5	11.5	14.5	17.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	22.57	23.06	23.20	23.59	23.90	24.18
C2	6.05	6.09	6.07	6.13	6.16	6.22
C3	11.11	11.13	10.92	10.94	10.96	11.03
C4	11.91	11.66	11.45	11.39	11.27	11.36
C5	11.83	11.48	11.35	11.40	11.28	11.22
C6	9.35	9.03	9.12	8.94	8.51	8.87
C7	6.67	6.51	6.44	6.41	6.33	6.27
C8	4.89	4.69	4.63	4.66	4.65	4.58
C9	3.45	3.43	3.37	3.47	3.33	3.34
C10	2.57	2.51	2.58	2.50	2.52	2.47
C11	1.94	1.83	1.84	1.78	1.85	1.74
C12	1.49	1.43	1.37	1.33	1.38	1.32
C13	1.10	1.05	1.01	0.97	0.99	0.96
C14	0.95	0.90	0.88	0.86	0.85	0.82
C15	1.14	1.01	1.00	1.01	0.97	0.95
alpha chain growth probability	0.68	0.68	0.68	0.68	0.68	0.67

C1 - C50 estimated total product distribution, weight %

C1	22.7	23.5	23.8	24.2	24.7	24.9
C2 - C4	29.3	29.5	29.2	29.2	29.3	29.4
C5 - C12	43.2	42.4	42.5	42.2	41.7	41.6
C13 - C50	4.8	4.6	4.5	4.4	4.3	4.1

CO conversion, %	2.5	2.5	2.4	2.4	2.3	2.2
rate, g CH ₂ /g cat/hr	0.14	0.14	0.14	0.13	0.13	0.13
CO ₂ formation, %						

Performance of Co.067

Dates: 06/21/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	20.5	23.5	26.5	29.5	32.5	35.5
reaction temperature, °C	220	220	220	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	24.15	25.95	30.58	66.56	60.66	58.94
C2	6.19	6.88	8.07	12.18	11.49	11.25
C3	10.93	11.85	13.86	10.76	12.36	12.61
C4	11.19	11.45	13.36	5.41	6.86	7.19
C5	11.15	11.00	12.69	2.65	3.88	4.34
C6	8.72	8.39	9.53	0.95	1.86	2.22
C7	6.31	5.87	3.22	0.46	0.95	1.15
C8	4.60	4.03	2.14	0.30	0.55	0.69
C9	3.35	2.59	1.52	0.20	0.33	0.38
C10	2.50	1.98	1.06	0.10	0.17	0.23
C11	1.77	1.41	0.78	0.08	0.10	0.14
C12	1.29	1.03	0.52	0.04	0.07	0.11
C13	0.95	0.72	0.38	0.03	0.07	0.07
C14	0.82	0.53	0.30	0.02	0.04	0.07
C15	0.96	0.64	0.29	0.03	0.04	0.09
alpha chain growth probability	0.67	0.64	0.62	0.46	0.53	0.55

C1 - C50 estimated total product distribution, weight %

C1	25.0	27.3	30.9	66.6	60.9	59.1
C2 - C4	29.2	31.7	35.6	28.4	30.8	31.1
C5 - C12	41.6	38.4	32.2	4.9	8.2	9.5
C13 - C50	4.2	2.6	1.4	0.1	0.2	0.3

CO conversion, %	2.2	1.9	1.7	13.1	8.0	6.5
rate, g CH ₂ /g cat/hr	0.13	0.11	0.10	0.74	0.45	0.37
CO ₂ formation, %						

Performance of Co.067
 Dates: 06/21/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	38.5	41.5	44.5	47.5	50.5	53.5
reaction temperature, °C	280	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	57.59	56.55	55.40	55.54	56.87	55.06
C2	11.09	11.07	11.07	11.30	10.87	11.48
C3	12.76	12.85	12.87	12.90	11.73	12.37
C4	7.39	7.53	7.60	7.49	7.12	7.35
C5	4.65	4.84	4.99	4.91	4.88	5.03
C6	2.46	2.62	2.82	2.66	2.57	2.46
C7	1.33	1.46	1.62	1.59	1.71	1.86
C8	0.82	0.86	0.99	0.96	1.07	1.18
C9	0.45	0.50	0.57	0.57	0.63	0.68
C10	0.28	0.29	0.35	0.34	0.42	0.37
C11	0.16	0.19	0.25	0.25	0.29	0.25
C12	0.13	0.12	0.18	0.15	0.18	0.19
C13	0.10	0.12	0.11	0.14	0.14	0.16
C14	0.07	0.09	0.10	0.10	0.12	0.14
C15	0.07	0.08	0.09	0.10	0.12	0.14
alpha chain growth probability	0.55	0.56	0.57	0.57	0.57	0.58

C1 - C50 estimated total product distribution, weight %

C1	57.8	56.8	55.7	55.9	57.4	55.4
C2 - C4	31.3	31.6	31.7	31.9	30.0	31.4
C5 - C12	10.6	11.3	12.1	11.8	12.2	12.6
C13 - C50	0.3	0.4	0.4	0.4	0.5	0.6

CO conversion, %	5.5	4.8	4.2	4.0	2.4	2.4
rate, g CH ₂ /g cat/hr	0.31	0.27	0.24	0.23	0.14	0.13
CO ₂ formation, %						

Performance of Co.067
 Dates: 06/21/95 - 01/00/00 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.9 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	56.5	59.5	62.5	65.5	68.5	71.5
reaction temperature, °C	280	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	52.76	49.08	48.91	45.85	43.56	47.86
C2	11.69	11.59	12.29	12.24	13.28	13.70
C3	12.53	12.21	12.67	12.35	13.83	12.80
C4	7.53	7.38	7.77	7.59	8.55	7.82
C5	5.18	5.18	5.60	5.48	6.22	5.77
C6	2.83	6.55	3.16	5.29	3.45	0.91
C7	2.03	2.03	2.28	2.71	2.68	2.55
C8	1.22	1.36	1.62	1.85	1.87	1.76
C9	0.79	0.88	1.01	1.17	1.21	1.15
C10	0.53	0.61	0.76	0.84	0.88	0.82
C11	0.40	0.46	0.53	0.60	0.65	0.64
C12	0.31	0.34	0.33	0.54	0.44	0.42
C13	0.22	0.22	0.27	0.38	0.39	0.35
C14	0.16	0.19	0.26	0.23	0.27	0.25
C15	0.14	0.16	0.20	0.24	0.26	0.26
alpha chain growth probability	0.59	0.60	0.62	0.61	0.62	0.62

C1 - C50 estimated total product distribution, weight %

C1	53.4	49.6	49.6	46.9	44.3	49.0
C2 - C4	32.1	31.5	33.2	32.9	36.3	35.2
C5 - C12	13.8	18.0	16.1	19.1	18.2	14.7
C13 - C50	0.7	0.8	1.2	1.0	1.2	1.1

CO conversion, %	2.1	2.0	1.7	1.6	2.0	1.2
rate, g CH ₂ /g cat/hr	0.12	0.11	0.10	0.09	0.11	0.07
CO ₂ formation, %						

CO Hydrogenation on Co.067 - ASF Product Distribution

CO Hydrogenation on Co.067

CO Hydrogenation on Co.067

Co.068 - Run #1

Co wt%	NM wt %	Promotor wt%		Support
20	Pd 1.00			Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm
 T = 220 °C
 H₂/CO = 2
 weight of catalyst = 0.201 g
 WHSV = 12.80 1/hr
 time on stream = 23.5 hrs

CO₂ (% of CO) =
 O/P = 0.01
 0.00

CO conversion (%)	4.0
rate (g CH ₂ /g cat/hr)	0.22
alpha	0.62
C1 (wt%)	28.8
C2 - C4 (wt%)	30.6
C5 - C12 (wt%)	38.7
C13 + (wt%)	1.9

Performance of Co.068

Dates: 06/26/95 - 06/29/95 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	2.5	5.5	8.5	11.5	14.5	17.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	26.52	27.34	27.20	27.45	28.47	27.95
C2	5.53	5.68	5.59	5.60	5.77	5.63
C3	11.57	12.09	11.92	11.96	12.32	12.07
C4	12.96	13.29	12.93	12.93	13.19	12.86
C5	12.76	12.84	12.58	12.54	12.91	12.46
C6	9.87	9.88	9.58	9.53	9.83	9.45
C7	6.47	6.46	6.30	6.32	6.43	5.70
C8	4.32	4.35	4.21	4.21	4.26	4.71
C9	2.88	2.86	2.80	2.77	0.03	2.66
C10	1.99	0.03	1.87	1.75	1.84	1.88
C11	1.29	1.31	1.23	1.29	1.25	1.20
C12	0.89	0.81	0.83	0.81	0.84	0.75
C13	0.57	0.56	0.54	0.54	0.50	0.53
C14	0.47	0.39	0.37	0.37	0.36	0.34
C15	0.42	0.34	0.35	0.32	0.31	0.29
alpha chain growth probability	0.64	0.63	0.63	0.63	0.63	0.62

C1 - C50 estimated total product distribution, weight %

C1	26.3	27.4	27.2	27.5	28.6	28.1
C2 - C4	29.9	31.1	30.4	30.6	31.4	30.7
C5 - C12	41.0	39.2	40.0	39.7	37.9	39.3
C13 - C50	2.8	2.3	2.4	2.1	2.1	1.9

CO conversion, %	4.2	4.1	4.3	4.3	4.1	4.2
rate, g CH ₂ /g cat/hr	0.24	0.23	0.24	0.24	0.23	0.24
CO ₂ formation, %						

Performance of Co.068

Dates: 06/26/95 - 06/29/95 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	20.5	23.5	26.5	29.5	32.5	35.5
reaction temperature, °C	220	220	220	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	28.31	28.64	33.49	76.42	63.85	59.62
C2	5.62	5.66	6.32	9.68	10.46	10.91
C3	11.98	12.10	12.70	7.74	12.05	12.81
C4	12.69	12.74	12.60	3.66	6.50	7.22
C5	12.44	12.30	11.49	1.52	3.63	4.40
C6	9.29	9.15	8.13	0.42	1.73	2.33
C7	5.68	6.14	5.20	0.15	0.76	1.09
C8	4.64	4.09	3.58	0.16	0.55	0.82
C9	2.75	2.70	2.10	0.12	0.24	0.40
C10	1.89	1.78	1.34	0.04	0.12	0.19
C11	1.25	1.29	0.73	0.04	0.08	0.13
C12	0.80	0.75	0.42	0.02	0.02	0.05
C13	0.49	0.48	0.30	0.02	0.02	0.03
C14	0.37	0.35	0.21	0.01	0.00	0.00
C15	0.28	0.28	0.17	0.00	0.00	0.00
alpha chain growth probability	0.62	0.62	0.59	0.44	0.42	0.46

C1 - C50 estimated total product distribution, weight %

C1	28.5	28.8	33.6	76.4	63.9	59.6
C2 - C4	30.4	30.6	31.7	21.1	29.0	30.9
C5 - C12	39.2	38.7	33.6	2.5	7.1	9.4
C13 - C50	1.9	1.9	1.1	0.0	0.0	0.1

CO conversion, %	3.8	4.0	2.4	15.8	7.6	5.6
rate, g CH ₂ /g cat/hr	0.22	0.22	0.13	0.88	0.42	0.31
CO ₂ formation, %						

Performance of Co.068
 Dates: 06/26/95 - 06/29/95 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	38.5	41.5	44.5	48.8	51.8	54.8
reaction temperature, °C	280	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	56.38	50.32	48.69	46.69	45.90	44.80
C2	11.37	11.15	12.71	13.33	13.80	14.32
C3	13.22	12.64	14.66	14.76	14.72	14.75
C4	7.66	7.46	8.80	8.93	8.89	8.96
C5	4.96	7.73	6.13	6.30	6.38	6.45
C6	2.77	4.48	3.69	3.95	3.70	3.79
C7	1.39	2.36	1.96	2.34	2.49	2.59
C8	1.10	1.69	1.56	1.54	1.64	1.72
C9	0.54	0.87	0.79	0.91	1.01	1.10
C10	0.34	0.65	0.46	0.62	0.68	0.71
C11	0.17	0.34	0.27	0.34	0.38	0.41
C12	0.10	0.17	0.17	0.18	0.28	0.25
C13	0.00	0.13	0.10	0.12	0.12	0.14
C14	0.00	0.00	0.00	0.00	0.00	0.00
C15	0.00	0.00	0.00	0.00	0.00	0.00
alpha chain growth probability	0.49	0.53	0.53	0.53	0.56	0.55

C1 - C50 estimated total product distribution, weight %

C1	56.3	50.3	48.6	46.6	45.7	44.7
C2 - C4	32.2	31.2	36.1	37.0	37.3	37.9
C5 - C12	11.4	18.2	15.0	16.1	16.6	17.0
C13 - C50	0.1	0.2	0.2	0.2	0.4	0.4

CO conversion, %	4.5	4.0	4.3	3.5	2.7	2.4
rate, g CH ₂ /g cat/hr	0.25	0.22	0.24	0.20	0.15	0.14
CO ₂ formation, %						

Performance of Co.068
 Dates: 06/26/95 - 06/29/95 Run #1

flow rate = 90.0 cc/min, loading = 0.2 g, WHSV = 12.8 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	57.8	61.8	64.8	67.8	70.6	0.0
reaction temperature, °C	280	280	280	280	220	0
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	0.0

C1 - C15 product distribution, weight %

C1	43.90	43.05	42.88	43.27	34.84	0.00
C2	14.78	15.13	15.61	16.11	19.21	0.00
C3	14.83	14.98	15.06	15.29	14.10	0.00
C4	9.01	9.04	9.14	9.13	14.42	0.00
C5	6.54	6.49	6.68	6.55	10.03	0.00
C6	3.97	4.06	2.98	2.14	2.36	0.00
C7	2.66	2.69	2.77	2.79	2.02	0.00
C8	1.79	1.80	1.90	1.84	1.29	0.00
C9	1.08	1.09	1.15	1.16	0.93	0.00
C10	0.70	0.75	0.77	0.81	0.79	0.00
C11	0.46	0.48	0.42	0.47	0.00	0.00
C12	0.28	0.29	0.34	0.27	0.00	0.00
C13	0.00	0.14	0.17	0.17	0.00	0.00
C14	0.00	0.00	0.13	0.00	0.00	0.00
C15	0.00	0.00	0.00	0.00	0.00	0.00
alpha chain growth probability	0.56	0.56	0.57	0.56	0.54	0.00

C1 - C50 estimated total product distribution, weight %

C1	43.7	42.9	42.7	43.2	34.5	0.0
C2 - C4	38.5	39.0	39.7	40.4	47.2	0.0
C5 - C12	17.4	17.6	17.1	16.0	18.0	0.0
C13 - C50	0.4	0.4	0.5	0.4	0.4	0.0

CO conversion, %	2.2	1.9	1.7	1.5	0.2	0.0
rate, g CH ₂ /g cat/hr	0.12	0.11	0.10	0.08	0.01	0.00
CO ₂ formation, %						

CO Hydrogenation on Co.068 - ASF Product Distribution

CO Hydrogenation on Co.068

CO Hydrogenation on Co.068

CoW.05 - Run #X

Co wt%	NM wt %	Promotor wt%		Support
20		Cu 5.00	Cr 4.00	Al ₂ O ₃

SUMMARY REACTION DATA

Reaction Conditions:

P = 1.0 atm

T = 220 °C

H₂/CO = 2

weight of catalyst = 0.400 g

WHSV = 6.43 1/hr

time on stream = 26.5 hrs

CO₂ (% of CO) =
O/P = 0

0.00

CO conversion (%)	0.8
rate (g CH ₂ /g cat/hr)	0.02
alpha	0.64
C1 (wt%)	32.8
C2 - C4 (wt%)	37.8
C5 - C12 (wt%)	26.7
C13 + (wt%)	2.6

Performance of CoW.05

Dates: 06/01/95 - 06/04/95 Run #X

flow rate = 90.0 cc/min, loading = 0.4 g, WHSV = 6.4 l/hr, H₂/CO ratio in feed = 2

time on stream, hr	2.5	5.5	8.5	11.5	17.5	20.5
reaction temperature, °C	220	220	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	90.0	90.0	90.0	90.0

C1 - C15 product distribution, weight %

C1	35.75	35.98	35.97	36.19	31.50	30.44
C2	10.52	10.71	10.86	10.95	10.16	9.90
C3	15.84	16.01	16.01	16.20	14.42	13.77
C4	12.82	12.62	12.59	12.76	11.92	11.52
C5	9.59	9.40	9.38	9.30	9.49	8.98
C6	5.43	5.35	5.25	5.24	5.57	5.41
C7	3.49	3.24	3.22	3.22	3.77	3.63
C8	2.12	1.94	1.97	1.79	2.50	2.30
C9	1.24	1.13	1.15	1.11	1.88	1.73
C10	0.81	0.75	0.74	0.68	1.48	1.37
C11	0.57	0.49	0.51	0.46	1.14	1.10
C12	0.44	0.33	0.29	0.26	0.80	0.81
C13	0.27	0.24	0.24	0.23	0.69	0.66
C14	0.26	0.21	0.20	0.19	0.62	0.64
C15	0.41	0.26	0.24	0.23	0.75	0.77
alpha chain growth probability	0.59	0.57	0.58	0.57	0.65	0.66

C1 - C50 estimated total product distribution, weight %

C1	35.6	36.3	36.2	36.4	31.9	32.0
C2 - C4	39.0	39.7	39.7	40.1	37.0	37.0
C5 - C12	24.2	23.2	23.2	22.7	28.1	27.8
C13 - C50	1.1	0.7	0.9	0.8	2.9	3.2

CO conversion, %	1.2	1.1	1.0	1.0	0.8	0.8
rate, g CH ₂ /g cat/hr	0.03	0.03	0.03	0.03	0.02	0.02
CO ₂ formation, %						

Performance of CoW.05

Dates: 06/01/95 - 06/04/95 Run #X

flow rate = 90.0 cc/min, loading = 0.4 g, WHSV = 6.4 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	23.5	26.5	32.5	35.5	38.5	41.5
reaction temperature, °C	220	220	220	220	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	90.0	90.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	30.56	31.24	33.31	34.87	70.69	63.71
C2	10.09	10.18	10.65	11.15	10.68	10.73
C3	14.08	14.16	14.79	15.46	9.36	11.81
C4	11.54	11.69	11.36	11.93	4.49	5.75
C5	8.89	8.99	8.58	8.99	2.21	2.88
C6	5.56	5.08	4.98	4.81	0.86	1.27
C7	3.48	3.57	3.22	3.27	0.52	1.14
C8	2.22	2.22	1.90	2.03	0.36	0.70
C9	1.63	1.61	1.42	1.50	0.23	0.43
C10	1.17	1.22	1.04	1.06	0.12	0.26
C11	1.00	0.99	0.82	0.90	0.09	0.15
C12	0.69	0.66	0.50	0.53	0.04	0.10
C13	0.59	0.55	0.41	0.44	0.04	0.07
C14	0.55	0.55	0.41	0.43	0.03	0.06
C15	0.80	0.69	0.52	0.55	0.03	0.07
alpha chain growth probability	0.64	0.64	0.63	0.63	0.53	0.56

C1 - C50 estimated total product distribution, weight %

C1	32.3	32.8	34.9	35.1	70.7	64.1
C2 - C4	37.8	37.8	38.6	38.8	24.6	28.5
C5 - C12	27.2	26.7	24.5	24.1	4.6	7.2
C13 - C50	2.7	2.6	2.0	1.9	0.1	0.3

CO conversion, %	0.7	0.8	0.8	0.8	10.2	7.5
rate, g CH ₂ /g cat/hr	0.02	0.02	0.02	0.02	0.29	0.21
CO ₂ formation, %						

Performance of CoW.05
 Dates: 06/01/95 - 06/04/95 Run #X

flow rate = 90.0 cc/min, loading = 0.4 g, WHSV = 6.4 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	47.5	50.5	53.5	56.5	59.5	62.5
reaction temperature, °C	280	280	280	280	280	280
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	61.52	59.48	58.17	56.66	55.71	54.63
C2	11.20	11.49	11.81	12.08	12.34	12.52
C3	13.07	13.66	13.88	14.04	14.11	14.05
C4	6.37	6.61	6.77	6.92	7.02	7.06
C5	3.32	3.59	3.76	3.96	4.07	4.18
C6	1.59	1.78	1.88	2.04	2.05	2.49
C7	0.89	1.01	1.06	1.27	1.30	1.38
C8	0.52	0.63	0.66	0.74	0.79	0.87
C9	0.32	0.37	0.42	0.45	0.50	0.55
C10	0.18	0.21	0.24	0.26	0.29	0.32
C11	0.12	0.17	0.17	0.15	0.18	0.21
C12	0.07	0.09	0.10	0.10	0.14	0.16
C13	0.07	0.07	0.08	0.09	0.10	0.12
C14	0.05	0.06	0.07	0.08	0.09	0.10
C15	0.06	0.07	0.08	0.09	0.10	0.11
alpha chain growth probability	0.54	0.52	0.55	0.56	0.56	0.57

C1 - C50 estimated total product distribution, weight %

C1	61.8	59.9	58.5	57.1	56.2	55.1
C2 - C4	30.8	32.0	32.6	33.3	33.8	33.9
C5 - C12	7.3	8.0	8.6	9.3	9.7	10.5
C13 - C50	0.2	0.2	0.3	0.3	0.4	0.4

CO conversion, %	6.1	5.4	4.9	4.4	4.1	3.8
rate, g CH ₂ /g cat/hr	0.17	0.15	0.14	0.12	0.11	0.11
CO ₂ formation, %						

Performance of CoW.05 Dates: 06/01/95 - 06/04/95 Run #X

flow rate = 90.0 cc/min, loading = 0.4 g, WHSV = 6.4 1/hr, H₂/CO ratio in feed = 2

time on stream, hr	65.5	68.5	71.5	74.5	77.5	80.5
reaction temperature, °C	280	280	220	220	220	220
pressure, atm	1.0	1.0	1.0	1.0	1.0	1.0
flow, cc/min	120.0	120.0	120.0	120.0	120.0	120.0

C1 - C15 product distribution, weight %

C1	53.77	53.75	29.67	28.28	28.48	28.36
C2	12.70	12.95	13.24	12.64	12.67	12.71
C3	14.02	14.11	12.76	12.18	12.26	12.39
C4	7.15	7.23	10.01	9.69	9.94	9.73
C5	4.29	4.35	6.92	7.69	7.80	7.82
C6	2.59	2.20	2.51	2.26	2.29	2.29
C7	1.48	1.49	3.17	3.48	3.53	3.57
C8	0.93	0.94	2.36	2.54	2.53	2.51
C9	0.60	0.60	1.91	2.13	2.00	1.97
C10	0.38	0.38	1.53	1.67	1.66	1.59
C11	0.26	0.25	1.32	1.44	1.35	1.35
C12	0.17	0.19	0.98	1.27	1.10	1.03
C13	0.13	0.14	0.91	0.94	0.99	0.93
C14	0.11	0.11	0.85	0.82	0.78	0.88
C15	0.12	0.12	0.96	1.06	0.96	1.03
alpha chain growth probability	0.58	0.58	0.69	0.69	0.68	0.69

C1 - C50 estimated total product distribution, weight %

C1	54.3	54.2	32.3	31.4	31.5	31.1
C2 - C4	34.2	34.6	39.2	38.3	38.5	38.2
C5 - C12	11.1	10.8	23.9	25.8	25.6	25.7
C13 - C50	0.5	0.5	4.7	4.6	4.3	4.9

CO conversion, %	3.6	3.4	0.3	0.3	0.3	0.4
rate, g CH ₂ /g cat/hr	0.10	0.10	0.01	0.01	0.01	0.01
CO ₂ formation, %						

CO Hydrogenation on CoW.05 - ASF Product Distribution

CO Hydrogenation on CoW.05

CO Hydrogenation on CoW.05

APPENDIX C

CHRONOLOGY OF RUNS IN SLURRY BUBBLE COLUMN REACTORS

APPENDIX C

CHRONOLOGY OF RUNS MADE IN THE SLURRY BUBBLE COLUMN REACTORS DURING THE SECOND QUARTER OF 1995

Task 2.0 -- Catalyst Testing

Subtask 2.2 - Slurry Bubble Column Testing

Run No. 40 in the M3-SBCR was started on April 13th with a charge of 15.0 gm of Catalyst No. Co.063. This catalyst contained 20% Co plus 8.5% La_2O_3 on alumina support. The CO conversion at startup conditions was only 8.7% which is considerably lower than 28% CO conversion obtained with Catalyst No. Co.058 that contained 1.0% La_2O_3 . Too much La_2O_3 had a negative effect on catalyst activity.

Run No. 41 in the M3-SBCR was started on April 19th with a charge of 15.0 gm of Catalyst No. Co.062. This catalyst contained 30% Co with 0.5% Ru metal and 1.5% K promoter on alumina support. The CO conversion at startup conditions was only 6.6% which is considerably lower than that obtained with similar catalysts containing 0.5, 0.3, and 0.1% K. Apparently, the amount of K added was too high.

Run No. 42 in the M3-SBCR was started on April 26th with a charge of 15.9 gm of Catalyst No. Co.065. This catalyst contained 20% Co with 0.5% Ru, 8.5% Zr, and 0.3% K promoters on alumina support. The CO conversion at startup conditions was 27.6%, the total hydrocarbon production rate was 1.25 g C_1 + /g cat/hr, and the CH_4 selectivity was 7.85%. These results were almost identical to those obtained with Catalyst No. Co.047 which contained 0.5% Ru and 0.3% K, but no Zr. The addition of Zr to alumina supported catalysts has little or no effect on the catalyst activity.

Run No. 43 in the M3-SBCR was started on May 8th with a charge of 9.1 gm of Catalyst No. CoW.12. This catalyst contained 10% Co, 10% Fe, with 0.5% Ru on silica support. The CO conversion at startup conditions was 6.1%, the THC production rate was 0.47 g C_1 + /g cat/hr, the CH_4 selectivity was 20.3%, and the CH_2 selectivity was 7.3%. Unfortunately, there was only 60% of the normal catalyst charge amount available which resulted in lower CO conversion. The presence of Fe in the catalyst, however, yielded low CO conversion and higher CH_4 selectivity increased to 32.4%.

Run No. 44 in the M3-SBCR was started on May 17th with a charge of 15.6 gm of Catalyst No. CoW.11. This catalyst contained 10% CO_2 , 10% Fe, with 0.5% Ru and 0.5% K on alumina support. The CO conversion at startup conditions was quite low, 4.7%, with a CH_4 selectivity of 8.4%. The CO conversion increased to 24.5% at 280°C reaction temperature while the CH_4 selectivity increased to 25.6%.

Run No. 45 in the M3-SBCR was started on May 24th with a charge of 15.9 gm of Catalyst No. Fe.01. This was the only iron catalyst without Co that has been tested. It contained 30% Fe plus 1.5% Cu on silica support. The CO conversion at startup conditions was quite low, 3.4%, while the CH₄ selectivity was too low to detect. The CO conversion increased to 14.5% at 280°C and 19.0% at 300°C reaction temperature. The CH₄ and CO₂ product selectivities at 300°C were 23.3% and 26.7% respectively. In general, the iron catalysts had much lower activity and produced more CH₄ and CO₂ than cobalt catalysts in the slurry bubble catalytic reactors.

Run No. 46 in the M3-SBCR was started on June 1st with a charge of 15.7 gm of Catalyst No. CoW.05. This catalyst contained 20% Co, 5.0% Cu, and 4.0% Zr on alumina support. The CO conversion at startup conditions was quite low, 4.87%, with a CH₄ selectivity of 10.9%. The CO conversion increased to 14.0% at 280°C reaction temperature while the CH₄ selectivity increased to 44.2%. At 300°C, the CO conversion peaked at 19.4% and the CH₄ selectivity reached 54.4%.

Run No. 47 in the M3-SBCR was started on June 21st with a charge of 15.6 gm of Catalyst No. Co.070. This catalyst contained 13% Co on alumina support with no promoters. The CO conversion at startup conditions was 22.8% with a CH₄ selectivity of 10.93%. The CO conversion dropped to 8.6% at 220°C reaction temperature and increased to 19.8% later in the run when the temperature was raised back to 240°C. The CO conversions, CH₄ selectivities, and production rates with 13% Co catalyst were lower than those obtained with 20 and 30% Co catalysts, but not proportional to the Co concentration. The catalyst activity was higher than expected.

Subtask 2.3 - CSTR Testing

Three catalysts, CAL.13, Co.005, and Co.041, were taken by Bill Gall to the Center for Applied Energy Research of the University of Kentucky at Lexington, Kentucky to be run in their one liter autoclave reactor. The purpose was to obtain kinetic rates and high syngas conversion data. High CO conversions were attained with a maximum of 99% for Catalyst No. CAL.13. The complete run results will be available next month. Results for Catalyst Nos. Co.005, Co.041, plus one more catalyst will be available in a few weeks.

Task 4.0 - Catalyst Aging Studies

Run No. 34 in M4-SBCR was started on June 8th with a charge of 15.8 gm of Calcicat Catalyst No. CAL.13 to attempt an aging run at lower temperatures. The CO conversion was only 1.0% at 210°C reaction temperature, so the temperature was increased to 220°C. When the CO conversion reached only 2.5%, it was decided to terminate the run. The reactor was disassembled and most of the catalyst was found inside the internal filter and in the heavy product tank. Apparently, there was a crack or defect in the filter, so a new filter was installed.

Run No. 35 in the M4-SBCR was started on June 14th with a charge of 25.0 gm of Caldicat Catalyst No. CAL.13 to repeat Run No. 33. The CO conversion at 220°C was too high, 17.2%, so the reaction temperature was held at 212°C where the initial CO conversion was 8.87%. After 240 hours on-stream the CO conversion leveled out at 7.4% for the remainder of the run, a total of 524 hours on-stream. The average rate of deactivation of the catalyst was about 5.96 gm CO/Kg catalyst/hr per Kg CO converted. The deactivation rate at 240°C was 30 gm CO/Kg catalyst/hr per Kg CO converted; thereby, demonstrating that catalyst deactivation is dependent on temperature rather than on total syngas consumed.

APPENDIX D

SLURRY BUBBLE COLUMN REACTOR DATA

Table I

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C6-18, %	Comments
2	CO.001	16.5	1	162	177	225	450	2.0	20	15.9	0.70	2.3	0.8	96.4	0.53	0.98	0.88	5.00	2.27	25.2	
2	CO.001	16.5	2	202	228	200	450	2.0	20	3.9	0.17	0.0	0.0	99.9	0.00	0.81	0.91	0.00	0.00	21.7	
2	CO.001	16.5	3	254	280	240	450	2.0	20	30.9	1.36	11.7	1.8	85.5	1.04	0.87	0.77	2.63	1.64	22.4	
2	CO.001	16.5	4	302	323	225	450	1.2	20	9.9	0.59	0.7	0.3	98.4	0.67	0.76	0.90	0.00	7.14	29.4	
2	CO.001	16.5	5	350	372	225	450	2.0	20	15.3	0.68	6.0	1.0	92.5	0.49	0.84	0.88	4.00	2.70	23.1	
2	CO.001	16.5	6	398	420	225	300	2.0	20	12.5	0.55	6.1	1.1	92.2	0.63	0.79	0.86	4.35	2.86	21.7	
2	CO.001	16.5	7	446	468	240	300	2.0	20	22.9	1.02	16.5	0.8	81.5	1.16	0.71	0.79	3.03	1.79	22.4	
2	CO.001	16.5	8	494	516	240	600	2.0	20	29.9	1.33	12.6	1.6	85.0	0.84	0.76	0.82	2.63	1.69	22.4	
2	CO.001	16.5	9	517	540	240	600	2.0	0	29.5	1.31	12.0	1.7	85.3	0.96	0.76	--	2.50	1.56	22.4	
2	CO.001	16.5	9	541	564	240	600	2.0	0	28.4	1.26	10.4	1.7	87.1	0.89	0.77	--	3.03	1.72	--	
2	CO.001	16.5	9	565	588	240	600	2.0	0	27.9	1.27	11.1	1.7	86.2	0.93	0.76	--	3.03	1.72	--	
2	CO.001	16.5	9	589	612	240	600	2.0	0	27.0	1.20	10.7	1.7	86.7	0.89	0.76	0.82	2.78	2.00	--	
2	CO.001	16.5	10	637	660	240	600	2.0	20	26.4	1.17	11.0	1.7	86.4	0.85	0.77	0.83	2.86	1.96	22.4	G.C. Calib
2	CO.001	16.5	11	684	706	225	450	2.0	20	11.6	0.51	5.4	1.0	93.0	0.61	0.81	0.87	5.26	3.45	23.8	
3	CO.005	19.5	1	12	36	240	450	2.0	20	33.2	1.23	5.6	1.6	91.8	1.06	0.80	0.81	2.04	1.27	23.1	G.C. Calib
3	CO.005	19.5	2	60	84	220	450	2.0	20	15.0	0.56	2.9	0.6	96.2	0.24	0.86	0.87	4.55	3.23	21.7	
3	CO.005	19.5	3	108	132	240	450	1.2	20	18.5	0.94	6.9	1.0	91.3	0.85	0.81	--	5.88	3.85	26.6	
3	CO.005	19.5	4	156	179	240	450	2.0	20	29.6	1.11	11.5	1.8	85.8	0.91	0.76	0.78	2.22	1.39	21.7	
4	CO.002	20.1	1	37	59	240	450	2.0	20	36.1	1.32	22.9	3.2	72.4	1.51	0.66	0.77	0.65	0.31	16.8	
4	CO.002	20.1	2	85	106	220	450	2.0	20	16.6	0.60	3.8	1.1	94.7	0.35	0.84	0.88	2.44	0.89	--	
4	CO.002	20.1	3	133	149	210	600	1.0	20	5.2	0.28	0.0	0.0	99.1	0.87	0.89	0.94	0.00	0.00	--	Power Fail
5	CO.003	15.1	1	15	35	240	450	2.0	20	31.7	1.53	16.7	2.4	79.8	1.16	0.71	--	1.30	0.60	18.2	G.C. Calib
5	CO.003	15.1	2	61	83	220	450	2.0	20	13.2	0.63	5.1	1.0	93.4	0.51	0.82	0.90	4.55	1.89	--	
5	CO.003	15.1	3	88	107	240	450	2.0	20	28.4	1.37	15.1	2.4	81.4	1.11	0.75	--	1.45	0.97	--	
5	CO.003	15.1	4	133	155	240	450	1.0	20	13.1	0.95	4.2	1.2	93.3	1.24	0.83	0.88	6.67	3.70	--	
5	CO.003	15.1	5	181	203	240	600	1.0	20	13.4	0.97	3.9	1.1	93.7	1.30	0.81	--	5.26	3.45	30.1	
5	CO.003	15.1	6	217	227	240	450	2.0	20	25.4	1.23	14.9	2.4	81.7	1.03	0.73	--	1.89	1.19	--	
6	CO.011	15.3	1	13	35	240	450	2.0	20	14.3	0.67	7.6	1.6	89.4	1.42	0.78	0.83	4.17	2.57	21.7	
6	CO.011	15.3	2	61	83	220	450	2.0	20	5.1	0.23	0.0	0.0	97.2	2.78	0.87	0.82	--	--	--	
6	CO.011	15.3	3	88	107	240	450	2.0	20	13.5	0.63	5.4	1.7	91.1	1.86	0.79	--	4.00	2.83	--	
6	CO.011	15.3	4	133	155	240	450	1.0	20	6.3	0.44	0.4	1.0	95.5	3.05	0.82	0.88	--	--	--	
6	CO.011	15.3	5	181	203	240	600	1.0	20	6.7	0.46	0.2	0.9	96.0	2.91	0.84	0.89	12.00	3.67	27.3	G.C. Calib
6	CO.011	15.3	6	217	226	240	450	2.0	20	12.0	0.57	5.9	1.8	90.4	1.91	0.78	--	4.40	2.43	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. Wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	N2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C6-18, %	Comments
												%CH4	%C2	%C3+	%CO2			C3	C4		
7	CO.012	15.8	1	14	36	240	450	2.0	20	13.9	0.63	6.1	1.5	90.6	1.74	0.80	0.89	4.00	2.57	17.5	
7	CO.012	15.8	2	62	84	220	450	2.0	20	5.1	0.23	0.0	0.2	97.8	2.02	0.89	0.90	--	2.50	--	
7	CO.012	15.8	3	88	92	240	450	2.0	20	13.1	0.59	6.1	1.7	90.4	1.75	0.80	--	5.00	2.25	--	Power Fail
7	CO.012	15.8	4	134	156	240	450	1.0	20	3.9	0.26	4.8	2.3	86.3	6.64	0.70	0.85	16.00	3.50	--	
7	CO.012	15.8	5	182	204	240	600	1.0	20	4.3	0.28	0.1	2.1	91.6	9.29	0.75	0.82	8.50	3.50	30.8	
7	CO.012	15.8	6	218	227	240	450	2.0	20	7.2	0.32	7.3	3.2	85.1	4.45	0.70	--	5.00	3.17	--	
8	CO.015	15.0	1	14	35	240	450	2.0	20	28.3	1.37	12.7	2.0	84.1	1.24	0.76	0.80	1.61	1.07	19.6	G.C. Calib
8	CO.015	15.0	2	61	83	220	450	2.0	20	11.5	0.56	4.4	1.0	93.9	0.80	0.81	0.89	3.60	2.14	--	
8	CO.015	15.0	3	97	106	240	450	2.0	20	26.4	1.28	13.2	2.1	83.5	1.12	0.75	--	1.69	1.20	--	
8	CO.015	15.0	4	133	155	240	450	1.0	20	11.5	0.83	4.8	1.2	92.5	1.53	0.80	0.85	5.60	3.29	--	
8	CO.015	15.0	5	181	191	240	600	1.0	20	12.4	0.90	4.9	0.8	93.6	0.73	0.84	0.85	5.20	3.14	30.8	Power Fail
9	CO.011	15.0	1	13	35	240	450	2.0	20	18.5	0.89	8.8	1.7	88.8	0.77	0.78	0.83	3.18	1.85	20.3	G.C. Calib
9	CO.011	15.0	2	61	82	220	450	2.0	20	6.3	0.31	0.0	1.0	98.6	0.41	0.88	0.93	12.00	1.80	--	
9	CO.011	15.0	3	97	107	240	450	2.0	20	16.6	0.80	8.4	2.1	88.7	0.81	0.77	--	3.30	2.00	--	
9	CO.011	15.0	4	133	155	240	450	1.0	20	8.0	0.58	1.3	1.3	96.3	1.16	0.82	0.87	7.00	2.83	--	
9	CO.011	15.0	5	181	203	240	600	1.0	20	8.7	0.63	1.4	1.1	96.4	1.05	0.83	0.87	5.00	2.67	30.5	
9	CO.011	15.0	6	228	229	240	450	2.0	20	14.7	0.71	7.9	2.2	89.1	0.85	0.78	--	3.78	1.67	--	Power Fail
11	CO.017	15.0	1	9	31	240	450	2.0	20	27.2	1.32	11.2	1.8	85.9	1.14	0.77	0.80	2.09	1.20	30.8	
11	CO.017	15.0	2	55	79	220	450	2.0	20	11.4	0.55	5.0	0.0	94.8	0.22	0.88	0.90	5.00	3.20	--	
11	CO.017	15.0	3	81	103	240	450	2.0	20	25.9	1.26	11.7	1.6	85.6	1.14	0.77	--	1.95	1.26	--	
11	CO.017	15.0	4	129	151	240	450	1.0	20	11.6	0.84	5.0	0.0	93.9	1.19	0.82	0.86	25.0	2.88	--	
11	CO.017	15.0	5	177	199	240	600	1.0	20	11.6	0.84	4.2	0.0	94.7	1.17	0.86	0.86	24.0	1.63	21.0	G.C. Calib
11	CO.017	15.0	6	213	221	240	450	2.0	20	24.3	1.20	12.1	1.4	86.4	0.08	0.78	--	2.47	1.64	--	
12	CO.018	15.6	1	13	35	240	450	2.0	20	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	1.81	1.13	21.0	G.C. Calib
12	CO.018	15.6	2	61	80	220	450	2.0	20	12.6	0.59	2.8	0.0	97.1	0.08	0.90	0.88	--	--	--	
12	CO.018	15.6	3	97	107	240	450	2.0	20	27.9	1.30	9.4	1.9	87.7	1.03	0.75	--	2.65	2.17	--	
12	CO.018	15.6	4	133	155	240	450	1.0	20	12.4	0.86	3.3	0.0	95.0	1.67	0.80	0.86	--	--	--	
12	CO.018	15.6	5	181	203	240	600	1.0	20	13.0	0.90	3.2	0.0	94.9	1.86	0.80	0.85	--	--	38.5	
12	CO.018	15.6	6	217	226	240	450	2.0	20	26.4	1.22	10.1	1.4	86.8	1.74	0.73	--	2.89	2.05	--	

Table I
(Continued)

SUMMARY OF M3 S8C2 RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

(b) Conversion is total CO conversion over the period (%).

(c) Conversion and selectivities are calculated using H₂ as an internal

standard in the GC analysis of the offgas.

Prod. rate: Rate for production of total hydrocarbons, $C_1 + (kg/kg \text{ cat. hr})$.
Alphas: Based on GC analysis of offgas and liquid products.

(e) Alpha: Based on GC analysis of off-gas and liquid products.

Run Cat.	cat.	Per Time	Time	Stop	C	psi	CO	cc/hr	% Rate	%C4H6	%C2H4	%C2H6	GC	Liq	C3	C4	CG-18,x	Comments														
13 CO.016	14.7	1	16	35	240	450	2.0	20	26.4	1.31	8.3	1.7	89.3	0.68	0.78	0.81	2.00	1.41	21.7	G.C.Calib	TD weak.	--	--	--	--	--	--	32.2	than expected.			
13 CO.016	14.7	2	65	83	220	450	2.0	20	9.7	0.48	0.0	0.99	9.0	0.00	0.91	0.88	--	--	2.10	1.41	--	--	--	--	--	--	--	--	--	are lower		
13 CO.016	14.7	3	89	105	240	450	2.0	20	25.2	1.25	9.2	1.7	88.6	0.51	0.78	--	--	--	2.10	1.41	--	--	--	--	--	--	--	--	--	are lower		
13 CO.016	14.7	4	134	155	240	450	1.0	20	10.9	0.81	1.2	0.7	97.7	0.32	0.84	0.86	--	--	--	--	--	--	--	--	--	--	--	--	--	--	are lower	
13 CO.016	14.7	5	181	203	240	600	1.0	20	11.4	0.85	0.0	0.4	99.3	0.25	0.92	0.86	--	--	--	--	--	--	--	--	--	--	--	--	--	--	are lower	
13 CO.016	14.7	6	210	226	240	450	2.0	20	22.7	1.12	3.8	1.9	93.7	0.46	0.79	--	--	--	2.37	1.41	--	--	--	--	--	--	--	--	--	--	are lower	
14 CO.019	15.2	1	14	35	240	450	2.0	20	13.9	0.66	0.4	1.7	97.2	0.70	0.80	0.86	5.33	2.67	26.6	G.C.Calib	New TD	--	--	--	--	--	--	--	--	--	--	expected.
14 CO.019	15.2	2	66	83	220	450	2.0	20	3.8	0.18	0.0	1.7	96.7	1.56	0.88	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	expected.	
14 CO.019	15.2	3	88	105	240	450	2.0	20	12.2	0.57	0.0	2.0	96.3	1.67	0.80	--	--	--	5.60	3.80	--	--	--	--	--	--	--	--	--	--	expected.	
14 CO.019	15.2	4	133	155	240	450	1.0	20	--	--	--	--	--	--	0.85	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	expected.
14 CO.019	15.2	5	169	178	240	600	1.0	20	5.9	0.41	0.0	1.5	96.1	2.42	0.80	--	--	--	8.50	13.00	--	--	--	--	--	--	--	--	--	--	expected.	
14 CO.019	15.2	6	193	203	240	450	2.0	20	10.2	0.48	0.8	2.2	95.0	1.96	0.79	--	--	--	4.80	3.40	--	--	--	--	--	--	--	--	--	--	expected.	
14 CO.019	15.2	7	217	226	240	450	1.0	20	5.1	0.36	0.0	1.6	95.4	3.09	0.80	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	expected.	
18 CO.004	15.0	1	20	39	240	450	2.0	20	33.9	1.64	15.3	2.4	80.9	1.37	0.74	0.79	1.17	0.78	20.3	Repair G.C	--	--	--	--	--	--	--	--	--	--	--	Repair G.C
18 CO.004	15.0	2	66	87	220	450	2.0	20	15.1	0.73	4.1	1.6	94.0	0.29	0.81	0.85	3.83	2.25	--	--	--	--	--	--	--	--	--	--	--	--	Repair G.C	
18 CO.004	15.0	3	92	111	240	450	2.0	20	32.7	1.59	15.7	2.6	80.2	1.49	0.73	--	1.20	0.80	--	--	--	--	--	--	--	--	--	--	--	--	Repair G.C	
18 CO.004	15.0	4	138	159	240	450	1.0	20	14.7	1.06	4.1	1.2	93.2	1.44	0.80	0.83	6.17	3.75	--	--	--	--	--	--	--	--	--	--	--	--	Repair G.C	
18 CO.004	15.0	5	186	207	240	600	1.0	20	15.0	1.09	3.6	1.1	94.1	1.18	0.82	0.83	5.67	4.00	33.6	--	--	--	--	--	--	--	--	--	--	--	Repair G.C	
18 CO.004	15.0	6	214	230	240	450	2.0	20	28.4	1.38	14.9	2.5	86.5	1.13	0.73	--	1.58	1.03	--	--	--	--	--	--	--	--	--	--	--	--	Repair G.C	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	N2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities XCH4	XC2	XC3+	XC02	Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C6-18, %	Comments
19	CO.021	15.6	1	16	35	240	450	2.0	20	23.2	1.08	9.4	2.0	88.0	0.73	0.77	0.82	2.56	1.54	20.3	
19	CO.021	15.6	2	62	83	220	450	2.0	20	8.3	0.38	0.0	1.3	98.2	0.51	0.82	0.88	4.33	3.33	--	
19	CO.021	15.6	3	90	107	240	450	2.0	20	21.8	1.02	10.2	2.2	86.7	0.95	0.76	--	2.50	1.53	--	
19	CO.021	15.6	4	134	155	240	450	1.0	20	9.9	0.69	1.7	1.6	95.5	1.41	0.81	0.83	6.00	3.80	--	
19	CO.021	15.6	5	182	203	240	600	1.0	20	11.5	0.80	1.8	1.2	95.8	1.16	0.83	0.85	6.50	3.80	30.3	
19	CO.021	15.6	6	210	226	240	450	2.0	20	19.9	0.93	9.6	2.3	87.2	0.95	0.76	--	2.31	1.38	--	
20	CO.041	15.8	1	17	37	240	450	2.0	20	25.3	1.16	11.0	2.1	86.0	0.88	0.76	0.84	2.94	1.61	20.3	
20	CO.041	15.8	2	66	75	220	450	2.0	20	9.1	0.41	0.0	1.5	97.8	0.65	0.82	0.91	8.00	2.75	--	
20	CO.041	15.8	3	90	109	240	450	2.0	20	26.3	1.21	9.5	1.9	87.8	0.82	0.78	--	2.81	1.71	--	
20	CO.041	15.8	4	136	148	240	450	1.0	20	12.7	0.88	1.9	1.2	95.9	0.95	0.83	0.86	9.00	4.20	--	
20	CO.041	15.8	5	169	178	240	600	1.0	20	13.2	0.91	2.0	1.0	96.1	0.93	0.84	--	7.00	3.50	--	
20	CO.041	15.8	6	193	203	240	450	2.0	20	24.6	1.13	9.4	1.8	87.9	0.92	0.78	--	2.93	1.75	--	
21	CO.014	15.1	1	24	38	240	450	2.0	20	8.5	0.40	8.3	3.5	85.8	2.43	0.74	0.83	2.75	1.67	17.5	G.C. Calib
21	CO.014	15.1	2	68	86	220	450	2.0	20	3.2	0.15	0.0	2.3	93.4	4.31	0.76	0.86	3.50	3.00	--	
21	CO.014	15.1	3	93	110	240	450	2.0	20	7.1	0.34	8.7	3.0	85.9	2.46	0.71	--	3.00	2.00	--	
21	CO.014	15.1	4	138	157	240	450	1.0	20	2.2	0.15	0.0	2.8	89.3	7.92	0.67	0.84	9.00	4.00	--	
21	CO.014	15.1	5	186	206	240	600	1.0	20	2.1	0.15	0.0	2.6	94.8	2.68	0.71	0.81	4.50	3.50	--	
22	CO.040	14.5	1	19	32	240	450	2.0	20	1.8	0.09	0.0	4.0	94.1	1.89	0.71	0.82	2.50	2.00	--	G.C. Calib
22	CO.040	14.5	2	43	63	220	450	2.0	20	0.7	0.03	0.0	0.7	97.1	2.17	0.91	--	1.00	2.00	--	Shut down
23	CO.047	15.8	1	21	39	240	450	2.0	20	28.2	1.29	7.7	1.5	89.3	1.47	0.79	0.84	3.14	1.69	24.5	
23	CO.047	15.8	2			220	450	2.0	20	--	--	--	--	--	--	--	--	--	--	--	Repair G.C
23	CO.047	15.8	3	94	111	240	450	2.0	20	25.6	1.17	8.9	1.5	88.2	1.38	0.78	--	3.15	2.00	--	
23	CO.047	15.8	4	141	159	240	450	1.0	20	11.9	0.81	2.9	0.9	94.1	2.13	0.82	0.88	7.33	4.75	--	
23	CO.047	15.8	5	187	207	240	600	1.0	20	11.8	0.81	2.6	0.8	94.6	2.01	0.82	0.87	7.00	3.60	--	
23	CO.047	15.8	6	215	226	240	450	2.0	20	24.0	1.10	10.7	1.9	85.7	1.71	0.75	--	3.54	2.13	--	
24	CO.049	15.6	1	19	39	240	450	2.0	20	30.6	1.41	10.9	1.8	85.7	1.66	0.76	0.82	2.09	1.30	14.0	
24	CO.049	15.6	2	71	87	220	450	2.0	20	12.0	1.07	2.7	0.9	95.3	1.09	0.81	0.95	4.25	3.25	--	
24	CO.049	15.6	3	95	111	240	450	2.0	20	29.5	1.37	9.5	1.6	87.6	1.30	0.78	--	2.32	1.40	--	
24	CO.049	15.6	4	139	159	240	450	1.0	20	12.6	0.87	3.1	1.0	94.1	1.80	0.81	0.86	8.33	4.20	--	
24	CO.049	15.6	5	187	207	240	600	1.0	20	13.4	0.93	2.6	0.9	94.8	1.68	0.82	0.88	8.33	4.20	37.8	
24	CO.049	15.6	6	211	231	240	450	2.0	20	24.9	1.16	10.4	1.7	86.5	1.36	0.76	--	2.75	1.75	--	
25	CO.047	15.6	1	19	33	240	450	2.0	20	28.1	1.30	8.8	1.6	88.1	1.50	0.78	0.85	2.93	1.88	25.9	Repeat R23
25	CO.047	15.6	2	55	69	220	450	2.0	20	7.4	0.34	1.5	1.2	96.3	1.02	0.76	0.89	3.00	4.67	--	
25	CO.047	15.6	3	93	159	240	450	2.0	20	25.6	1.19	8.9	1.6	87.9	1.48	0.77	--	3.14	2.00	--	
25	CO.047	15.6	4	143	159	240	450	1.0	20	10.8	0.75	3.0	1.0	94.2	1.84	0.81	0.94	8.00	4.75	--	
25	CO.047	15.6	5	189	207	240	600	1.0	20	12.4	0.86	2.2	0.8	95.6	1.39	0.83	0.86	7.33	4.50	36.4	
25	CO.047	15.6	6	215	231	240	450	2.0	20	23.2	1.08	9.6	1.7	87.4	1.28	0.77	--	3.50	2.07	--	
26	CO.031	15.9	1	19	39	240	450	2.0	20	30.9	1.41	12.1	1.9	84.9	1.12	0.75	0.83	1.83	1.14	22.4	
26	CO.031	15.9	2	67	87	220	450	2.0	20	13.6	0.62	3.9	0.9	94.6	0.49	0.80	0.85	4.20	2.67	--	
26	CO.031	15.9	3	93	111	240	450	2.0	20	29.5	1.35	12.2	2.1	84.6	1.15	0.75	--	1.97	1.25	--	
26	CO.031	15.9	4	141	159	240	450	1.0	20	12.9	0.88	3.6	1.1	94.3	1.11	0.80	0.88	7.75	4.00	--	
26	CO.031	15.9	5	189	207	240	600	1.0	20	13.9	0.95	3.5	1.0	94.4	1.12	0.81	0.85	6.80	3.71	30.1	
26	CO.031	15.9	6	221	230	240	450	2.0	20	26.6	1.22	12.0	2.2	84.9	0.96	0.74	--	2.30	1.43	--	

Table I
(Continued)

SUMMARY OF M3 SCCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using H₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ : CO	Synfl CO	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin C3	Paraf C4	Olefins C5-18, %	Comments
27	CO.029	15.9	1	23	39	240	450	2.0	20	28.3	1.27	8.3	1.6	87.9	2.21	0.77	0.84	3.40	2.20	27.3	
27	CO.029	15.9	2	71	87	220	450	2.0	20	9.5	0.63	1.7	1.1	96.0	1.23	0.80	0.39	5.67	3.00	--	
27	CO.029	15.9	3	99	111	240	450	2.0	20	25.7	1.16	7.7	1.6	88.8	1.86	0.78	--	4.00	2.36	--	
27	CO.029	15.9	4	150	159	240	450	1.0	20	12.0	0.82	1.9	0.9	95.4	1.88	0.83	0.90	8.33	4.75	--	
27	CO.029	15.9	5	191	207	240	600	1.0	20	12.1	0.82	1.7	0.9	95.6	1.75	0.83	0.39	7.67	4.75	39.9	
27	CO.029	15.9	6	222	230	240	450	2.0	20	23.7	1.08	8.2	1.7	88.5	1.60	0.78	--	3.92	2.67	--	
28	CO.01	15.0	1	19	36	240	450	2.0	20	1.1	0.05	0.0	12.	83.9	4.23	0.58	--	3.33	2.50	--	Shut down
29	CO.053	25.2	1	21	39	240	450	2.0	20	42.0	1.19	15.8	2.3	79.5	2.42	0.73	--	1.00	0.67	17.5	
29	CO.053	25.2	2	71	87	220	450	2.0	20	20.5	0.59	5.7	4.8	89.0	0.50	0.79	0.84	3.38	2.10	--	
29	CO.053	25.2	3	95	111	240	450	2.0	20	39.2	1.13	15.8	2.9	79.2	2.09	0.72	--	1.11	0.74	--	
29	CO.053	25.2	4	143	159	240	450	1.0	20	18.4	0.79	5.3	2.6	90.6	1.52	0.80	0.84	5.86	3.56	--	
29	CO.053	25.2	5	191	207	240	600	1.0	20	19.7	0.85	4.6	1.2	92.9	1.34	0.82	--	5.71	3.44	33.6	
29	CO.053	25.2	6	239	255	240	600	2.0	20	40.8	1.17	14.8	2.1	81.4	1.68	0.75	0.80	1.10	0.74	--	
29	CO.053	25.2	7	303	304	240	450	2.0	20	31.5	0.45	21.0	3.9	72.2	2.93	0.63	--	1.34	0.97	--	G.C.Repair
29	CO.053	25.2	8	332	351	260	450	2.0	20	31.0	0.44	36.4	5.3	52.6	5.74	0.52	--	2.60	1.75	--	
29	CO.053	25.2	9	375	376	240	450	2.0	20	18.0	0.55	23.0	3.5	72.1	1.46	0.66	--	3.21	2.05	--	
29	CO.053	25.2	10	415	423	240	450	2.0	20	21.6	0.98	14.4	2.5	82.4	0.82	0.72	--	2.87	1.79	--	G.C.Repair
30	CO.053	29.6	1	26	39	240	450	2.0	20	41.8	1.02	22.6	2.9	71.5	3.05	0.66	--	0.99	0.65	19.6	
30	CO.053	29.6	2	55	63	260	450	2.0	20	46.9	1.11	40.6	5.5	46.0	7.98	0.45	--	0.83	0.64	--	
30	CO.053	29.6	3	79	87	280	450	2.0	20	41.4	0.96	41.9	6.5	42.0	9.63	0.40	--	2.06	1.35	--	
30	CO.053	29.6	4	103	111	240	450	2.0	20	19.9	0.49	19.2	3.6	75.8	1.45	0.64	--	4.29	2.50	--	
30	CO.053	29.6	5	131	135	265	450	2.0	20	36.4	0.89	36.4	5.2	54.4	4.04	0.53	--	2.45	1.60	--	
30	CO.053	29.6	6	154	159	280	450	2.0	20	39.6	0.96	48.3	5.9	39.0	6.84	0.40	--	2.44	1.62	--	
30	CO.053	29.6	7	174	183	300	450	2.0	20	40.7	0.94	42.4	6.8	40.7	10.2	0.47	--	3.11	2.03	--	
30	CO.053	29.6	8	198	207	309	450	2.0	20	38.3	0.85	22.8	7.3	58.3	11.6	0.62	--	3.76	2.48	--	G.C.Calib
30	CO.053	29.6	9	220	231	310	450	2.0	20	37.5	0.87	55.5	7.2	25.5	11.8	0.13	--	3.93	2.67	--	
30	CO.053	29.6	10	242	254	320	450	2.0	20	40.8	0.90	61.7	7.4	14.5	16.4	0.00	--	3.62	2.63	--	
30	CO.053	29.6	11	270	279	320	450	1.0	20	30.8	0.92	42.9	6.0	26.9	24.2	0.30	--	5.68	4.28	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres psi	N2: CO	Synfld cc/hr	Conv. %	Prod. Rate	Selectivity %	Alpha GC	Alpha Liq	Olefin C3	Paraf C4	Olefins C6-C18,%	Comments		
31	Co.055	15.0	1	23	39	240	450	2.0	20	30.0	1.46	23.7	3.73	70.2	0.61	0.81	0.90	0.60	20.3	
31	Co.055	15.0	2	71	87	220	450	2.0	20	9.1	0.44	10.6	2.53	85.7	0.61	0.85	2.89	1.80	--	
31	Co.055	15.0	3	98	110	240	450	2.0	20	25.8	1.26	23.9	3.94	70.1	0.58	--	1.06	0.70	--	
31	Co.055	15.0	4	143	159	240	450	1.0	20	14.7	1.06	5.5	1.44	91.7	0.78	0.83	5.71	3.22	--	
31	Co.055	15.0	5	196	207	240	600	1.0	20	16.1	1.16	4.7	1.21	92.8	0.80	0.83	6.17	3.11	33.6	
31	Co.055	15.0	6	222	234	240	450	2.0	20	29.1	1.42	18.0	2.84	77.8	0.69	--	1.40	0.91	--	
32	Co.044	16.4	1	23	39	240	450	2.0	20	20.9	0.93	6.7	1.91	90.8	0.77	0.83	3.42	2.17	23.1	
32	Co.044	16.4	2	71	87	220	450	2.0	20	10.3	0.46	0.0	0.92	98.8	0.85	--	4.33	4.50	--	
32	Co.044	16.4	3	102	110	240	450	2.0	20	21.8	0.97	6.4	1.72	91.3	0.79	--	3.00	1.77	--	
32	Co.044	16.4	4	143	159	240	450	1.0	20	9.87	0.25	2.1	3.19	92.5	0.61	0.87	7.33	4.00	--	
32	Co.044	16.4	5	174	182	240	450	2.0	20	20.2	0.89	6.8	1.85	90.8	0.79	--	2.92	1.75	--	
33	Co.053	31.4	1	24	39	240	450	2.0	20	41.4	0.94	23.2	3.14	69.6	0.65	0.76	0.82	0.58	21.7	G.C.Calib
33	Co.053	31.4	2	54	63	240	300	2.0	20	35.2	0.47	29.9	3.93	59.6	0.55	--	0.89	0.70	--	
33	Co.053	31.4	3	78	87	240	300	2.0	20	38.7	0.38	31.1	3.90	57.5	0.54	--	0.97	0.71	--	
33	Co.053	31.4	4	102	111	250	300	2.0	20	39.6	0.38	43.1	4.60	41.1	0.38	--	0.99	0.77	--	
33	Co.053	31.4	5	126	135	260	300	2.0	20	37.7	0.37	42.1	4.59	42.4	0.42	--	1.76	1.21	--	
33	Co.053	31.4	6	150	159	260	450	2.0	20	45.0	0.44	43.2	4.80	40.9	0.44	--	1.35	0.95	--	
33	Co.053	31.4	7	174	183	260	450	2.0	20	45.7	0.73	46.4	4.63	40.2	0.43	--	1.06	0.77	--	
33	Co.053	31.4	8	198	207	260	450	2.0	20	49.2	0.98	44.4	4.26	43.5	0.51	--	0.87	0.65	--	
33	Co.053	31.4	9	222	230	240	450	2.0	20	16.1	0.38	33.7	4.79	59.2	0.35	--	3.14	1.91	--	
34	Co.060	15.6	1	23	32	240	450	2.0	20	31.4	1.46	14.0	2.34	82.2	0.75	0.79	1.61	1.00	23.1	G.C.Calib
34	Co.060	15.6	2	71	87	220	450	2.0	20	13.0	0.60	0.1	1.77	97.8	0.81	0.88	4.00	2.83	--	G.C.Calib
34	Co.060	15.6	3	102	111	240	450	2.0	20	28.8	1.34	14.1	2.40	82.2	0.73	--	1.87	1.17	--	
34	Co.060	15.6	4	150	157	240	450	1.0	20	13.5	0.94	4.3	1.75	92.5	0.77	0.85	7.00	4.67	--	
34	Co.060	15.6	5	191	207	240	600	1.0	20	12.8	0.89	2.2	1.64	94.9	0.82	0.86	6.60	4.33	38.5	G.C.Calib
34	Co.060	15.6	6	222	230	240	450	2.0	20	24.9	1.16	13.8	2.78	82.2	0.74	--	2.73	1.73	--	
35	Co.041	26.0	1	23	39	240	450	2.0	20	35.7	1.00	13.6	2.13	82.9	0.79	0.82	1.09	0.74	18.2	
35	Co.041	26.0	2	54	63	250	450	2.0	20	42.1	1.17	27.3	4.61	64.4	0.65	--	0.49	0.41	--	G.C.Calib
35	Co.041	26.0	3	78	87	260	450	2.0	20	45.1	1.24	41.7	6.83	44.9	0.51	--	0.35	0.37	--	
35	Co.041	26.0	4	102	111	260	450	2.0	20	46.7	0.77	39.1	4.55	49.9	0.56	--	0.66	0.52	--	
35	Co.041	26.0	5	126	135	260	450	2.0	20	49.6	0.61	39.4	4.02	49.6	0.57	--	0.70	0.52	--	
35	Co.041	26.0	6	150	159	260	450	2.0	20	47.9	0.95	33.1	3.93	58.7	0.64	--	0.75	0.52	--	
35	Co.041	26.0	7	174	183	260	450	2.0	20	49.7	1.24	30.9	4.38	61.3	0.66	--	0.71	0.49	--	
35	Co.041	26.0	8	198	206	240	450	2.0	20	19.6	0.55	17.3	2.64	79.1	0.71	--	2.08	1.63	--	

Table I
(continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (X).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₆ -18, X	Comments
No	No		No									XCH ₄	XC ₂	XC ₃ +	XC ₄			C ₃	C ₄		
36	Co.032	15.9	1	23	39	240	450	2.0	20	24.0	1.10	9.1	1.8	88.2	0.83	0.77	0.83	3.23	2.00	25.2	
36	Co.032	15.9	2	71	87	220	450	2.0	20	7.7	0.35	0.0	1.5	97.8	0.77	0.81	0.91	4.00	3.33	--	
36	Co.032	15.9	3	102	111	240	450	2.0	20	21.1	0.97	8.7	2.4	88.2	0.68	0.78	--	3.08	1.86	--	G.C.Calib
36	Co.032	15.9	4	126	135	240	450	1.0	20	9.5	0.65	1.4	1.2	96.5	0.87	0.83	--	7.67	4.50	--	
36	Co.032	15.9	5	150	159	240	450	2.0	20	18.2	0.83	8.9	1.6	88.9	0.64	0.78	--	3.36	2.36	--	
36	Co.032	15.9	6	174	183	250	450	2.0	20	23.3	1.07	14.5	3.0	81.6	1.01	0.73	--	2.29	1.48	--	
36	Co.032	15.9	7	199	207	260	450	2.0	20	25.3	1.17	23.5	3.8	71.2	1.51	0.61	--	1.76	1.15	--	G.C.Calib
36	Co.032	15.9	8	222	230	240	450	2.0	20	11.0	0.51	10.4	2.9	85.9	0.88	0.67	--	3.33	2.33	--	
37	Co.045	15.9	1	23	39	240	450	2.0	20	14.8	0.67	8.0	1.7	89.4	0.91	0.76	0.84	2.78	1.90	20.3	
37	Co.045	15.9	2	54	63	220	450	2.0	20	5.1	0.23	0.0	1.5	97.7	0.77	0.80	0.88	4.00	3.00	--	
37	Co.045	15.9	3	78	87	240	450	2.0	20	13.8	0.63	8.2	1.9	89.0	0.89	0.76	--	3.00	1.80	--	
37	Co.045	15.9	4	102	111	240	450	1.0	20	6.5	0.44	0.1	1.4	97.3	1.16	0.82	--	5.00	2.00	--	
37	Co.045	15.9	5	126	135	240	450	2.0	20	13.4	0.61	0.6	1.8	88.9	0.80	0.79	--	2.00	0.00	--	
37	Co.045	15.9	6	150	159	250	450	2.0	20	19.6	0.91	17.5	2.5	80.0	--	0.77	--	--	0.00	--	G.C.Calib
37	Co.045	15.9	7	174	183	260	450	2.0	20	27.4	1.26	30.1	5.2	62.2	2.49	0.61	--	0.83	0.60	--	
37	Co.045	15.9	8	198	207	240	450	2.0	20	13.7	0.63	9.3	1.7	87.4	0.78	0.75	--	2.67	1.67	--	
38	Co.058	15.9	1	23	39	240	450	2.0	20	28.0	1.28	11.9	2.1	85.1	0.91	0.75	0.85	1.88	1.17	22.4	
38	Co.058	15.9	2	47	63	220	450	2.0	20	11.7	0.54	1.4	1.4	96.9	0.38	0.81	--	4.00	3.00	--	
38	Co.058	15.9	3	74	88	240	450	2.0	20	12.7	0.87	3.2	1.3	94.5	1.01	0.81	--	7.25	4.40	--	
38	Co.058	15.9	4	96	111	240	450	2.0	20	26.4	1.21	11.9	2.2	85.0	0.87	0.74	--	2.09	1.26	--	
39	Co.064	15.9	1	23	39	240	450	2.0	20	34.2	1.56	13.6	2.3	82.6	1.55	0.73	0.85	1.40	0.92	21.0	G.C.CALIB
39	Co.064	15.9	2	47	62	220	450	2.0	20	15.0	0.68	4.6	1.2	93.8	0.44	0.78	--	4.17	2.38	--	
39	Co.064	15.9	3	71	87	240	450	2.0	20	15.9	1.09	4.7	1.2	92.9	1.28	0.80	--	7.86	3.88	--	
39	Co.064	15.9	4	95	111	240	450	2.0	20	33.1	1.52	15.7	2.6	80.3	1.52	0.72	--	1.37	0.90	--	
40	Co.063	15.0	1	23	40	240	450	2.0	20	8.7	0.43	6.5	0.9	92.6	0.09	0.74	--	7.67	3.40	25.9	
40	Co.063	15.0	2	47	63	220	450	2.0	20	2.0	0.95	0.1	0.0	99.9	0.00	0.67	--	7.00	7.00	--	
40	Co.063	15.0	3	71	87	240	450	1.0	20	3.6	0.27	2.3	1.3	95.9	0.54	0.76	--	13.00	5.50	--	
40	Co.063	15.0	4	95	111	240	450	2.0	20	9.5	0.46	8.1	1.9	89.6	0.40	0.74	--	4.80	3.17	--	
41	Co.062	15.0	1	23	38	240	450	2.0	20	6.6	0.32	3.5	0.3	95.3	1.00	0.76	0.89	9.50	3.50	25.9	
41	Co.062	15.0	2	47	62	220	450	2.0	20	1.8	0.09	0.0	0.0	99.9	0.00	0.88	--	4.00	5.00	--	
41	Co.062	15.0	3	71	86	240	450	1.0	20	2.7	0.19	0.1	1.0	96.9	1.99	0.77	--	10.00	4.00	--	
41	Co.062	15.0	4	95	109	240	450	2.0	20	5.6	0.27	4.3	2.1	92.0	1.60	0.74	--	5.70	4.00	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C ₆ -18, %	Comments
No	No	wt, g	No	Start	Stop	C	psi	CO	cc/hr	%	Rate	CH ₄	C ₂	C ₃ +	CO ₂	GC	Liq	C ₃	C ₄	C ₆ -18, %	
42	Co.065	15.9	1	23	38	240	450	2.0	20	27.6	1.25	7.9	2.0	88.6	1.61	0.79	0.84	2.94	1.88	28.0	G.C. Calib
42	Co.065	15.9	2	47	62	220	450	2.0	20	10.0	0.46	0.0	2.0	97.3	0.67	0.82	--	5.33	3.25	--	
42	Co.065	15.9	3	71	86	240	450	1.0	20	13.1	0.89	1.2	1.5	95.7	1.67	0.84	--	7.00	5.50	--	
42	Co.065	15.9	4	95	110	240	450	2.0	20	26.2	1.19	9.0	2.1	87.3	1.57	0.78	--	3.06	2.13	--	
43	COW.12	9.1	1	23	38	240	450	2.0	20	6.1	0.47	20.3	6.1	66.3	7.29	0.61	0.83	3.63	2.33	11.9	
43	COW.12	9.1	2	54	62	279	450	2.0	20	25.1	1.86	32.4	5.4	51.3	11.0	0.52	--	1.62	1.12	--	
44	COW.11	15.6	1	23	38	240	450	2.0	20	4.7	0.20	8.4	6.3	74.4	10.9	0.60	--	5.40	3.50	--	
44	COW.11	15.6	2	47	62	260	450	2.0	20	12.7	0.51	18.6	6.1	59.8	15.4	0.56	--	4.57	3.00	--	
44	COW.11	15.6	3	71	80	280	450	2.0	20	24.5	0.94	25.6	6.3	47.3	20.8	0.49	--	3.38	2.29	--	
45	Fe.01	15.9	1	23	38	240	450	2.0	20	3.4	0.14	0.0	7.5	84.8	7.7	0.72	0.77	2.80	1.50	--	
45	Fe.01	15.9	2	71	62	280	450	2.0	20	14.5	0.55	17.2	8.8	54.0	19.9	0.54	--	1.51	1.00	--	
45	Fe.01	15.9	3	95	109	300	450	2.0	20	19.0	0.66	23.3	10.0	39.8	26.7	0.44	0.76	1.36	1.05	14.0	
46	COW.05	15.7	1	23	38	240	450	2.0	20	4.9	0.23	10.9	6.5	81.9	0.74	0.60	0.78	3.11	2.14	13.3	
46	COW.05	15.7	2	71	86	280	450	2.0	20	14.0	0.66	44.2	10.4	42.5	2.84	0.41	0.82	0.82	0.68	14.0	
46	COW.05	15.7	3	95	110	300	450	2.0	20	19.4	0.89	54.4	11.1	28.2	6.39	0.16	0.78	0.69	0.62	9.8	
47	Co.070	15.6	1	23	38	240	450	2.0	20	22.8	1.07	10.9	2.7	85.7	0.70	0.75	0.85	2.60	1.56	24.5	
47	Co.070	15.6	2	47	63	220	450	2.0	20	8.6	0.40	0.0	4.3	95.7	0.02	0.82	--	--	--	--	
47	Co.070	15.6	3	71	87	220	450	1.0	20	1.2	0.08	0.0	--	94.5	--	0.62	--	--	--	--	
47	Co.070	15.6	4	95	111	240	450	1.0	20	5.3	0.37	3.7	4.2	90.3	1.76	0.71	--	--	--	--	
47	Co.070	15.6	5	119	135	240	450	2.0	20	19.8	0.93	10.4	2.1	86.8	0.68	0.76	--	2.85	1.71	--	
47	Co.070	15.6	6	143	158	240	600	2.0	20	20.5	0.96	9.6	2.2	87.6	0.61	0.77	--	2.36	1.40	--	

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres psi	N2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C6-C18,X	Comments
---	-----	-----	---	-----	-----	-----	---	---	-----	---	-----	----	----	----	----	-----	-----	-----	-----	-----	-----
29	Co.053	25.2	1	21	39	240	450	2.0	20	42.0	1.19	15.8	2.3	79.5	2.42	0.73	--	1.00	0.67	17.5	
29	Co.053	25.2	2	71	87	220	450	2.0	20	20.5	0.59	5.7	4.8	89.0	0.50	0.79	0.84	3.38	2.10	--	
29	Co.053	25.2	3	95	111	240	450	2.0	20	39.2	1.13	15.8	2.9	79.2	2.09	0.72	--	1.11	0.74	--	
29	Co.053	25.2	4	143	159	240	450	1.0	20	18.4	0.79	5.3	2.6	90.6	1.52	0.80	0.84	5.86	3.56	33.6	
29	Co.053	25.2	5	191	207	240	600	1.0	20	19.7	0.85	4.6	1.2	92.9	1.34	0.82	0.85	5.71	3.44	--	
29	Co.053	25.2	6	239	255	240	600	2.0	20	40.8	1.17	14.8	2.1	81.4	1.68	0.75	0.80	1.10	0.74	--	
29	Co.053	25.2	7	303	304	240	450	2.0	20	31.5	0.45	21.0	3.9	72.2	2.93	0.63	--	1.34	0.97	--	G.C.Repair
29	Co.053	25.2	8	332	351	260	450	2.0	20	31.0	0.44	36.4	5.3	52.6	5.74	0.52	--	2.60	1.75	--	
29	Co.053	25.2	9	375	376	240	450	2.0	20	18.0	0.55	23.0	3.5	72.1	1.46	0.66	--	3.21	2.05	--	
29	Co.053	25.2	10	415	423	240	450	2.0	20	21.6	0.98	14.4	2.5	82.4	0.82	0.72	0.79	2.87	1.79	25.9	G.C.Repair

Feed Gas Rates

Per N2 H2 CO Total
No SLH SLH SLH SLH

1	565	225	112	902
2	565	225	112	902
3	565	225	112	902
4	565	169	169	903
5	565	169	169	903
6	565	225	112	902
7	733	112	56	901
8	733	112	56	901
9	551	234	117	912
10	367	348	175	890

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (Z).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt.,g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: Synfl CO	Conv. cc/hr	Prod. %	Rate	Selectivities IC3+ IC2 IC3+ IC02	Alpha GC	Alpha Liq	Olefin/Paraf C3 C4	Olefins C5-C18, Z	Comments
33	Co.053	31.4	1	24	39	240	450	2.0	20	41.4	0.94	23.2 3.1 69.6 4.06	0.65	0.76	0.82 0.58	21.7	G.C. Calib
33	Co.053	31.4	2	54	63	240	300	2.0	20	35.2	0.47	29.9 3.9 59.6 6.57	0.55	--	0.89 0.70	--	
33	Co.053	31.4	3	78	87	240	300	2.0	20	38.7	0.38	31.1 3.9 57.5 7.48	0.54	--	0.97 0.71	--	
33	Co.053	31.4	4	102	111	250	300	2.0	20	39.6	0.38	43.1 4.6 41.1 11.3	0.38	--	0.99 0.77	--	
33	Co.053	31.4	5	125	135	260	300	2.0	20	37.7	0.37	42.1 4.6 42.4 10.9	0.42	--	1.76 1.21	--	
33	Co.053	31.4	6	150	159	260	450	2.0	20	45.0	0.44	43.2 4.8 40.9 11.1	0.44	--	1.35 0.95	--	
33	Co.053	31.4	7	174	183	250	450	2.0	20	45.7	0.73	46.4 4.6 40.2 8.77	0.43	--	1.06 0.77	--	
33	Co.053	31.4	8	198	207	260	450	2.0	20	49.2	0.98	44.4 4.3 43.5 7.84	0.51	--	0.87 0.65	--	
33	Co.053	31.4	9	222	230	240	450	2.0	20	16.1	0.38	33.7 4.8 59.2 2.24	0.35	--	3.14 1.91	--	

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
--------	--------	--------	--------	-----------

1	563	225	112	900
2	338	135	67	540
3	250	100	50	400
4	250	100	50	400
5	250	100	50	400
6	250	100	50	400
7	160	160	80	400
8	100	200	100	400
9	563	225	112	900

Table I
(Continued)

SUMMARY OF M3 SBCR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (T).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Per wt, g	Time No	Time Start	Time Stop	Temp C	Pres psi	H ₂ CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C ₃	Olefins C ₄	Olefins C _{5-18, I}	Comments
35	CO.041	26.0	1	23	39	240	450	2.0	20	35.7	1.00	13.6	2.1	82.9	1.41	0.79	0.82	1.09	0.74	18.2	G.C. Calib
35	CO.041	26.0	2	54	63	250	450	2.0	20	42.1	1.17	27.3	4.6	64.4	3.78	0.65	--	0.49	0.41	--	
35	CO.041	26.0	3	78	87	260	450	2.0	20	45.1	1.24	41.7	6.8	44.9	6.58	0.51	--	0.35	0.37	--	
35	CO.041	26.0	4	102	111	260	450	2.0	20	46.7	0.77	39.1	4.6	49.9	6.40	0.56	--	0.66	0.52	--	
35	CO.041	26.0	5	126	135	260	450	2.0	20	49.6	0.61	39.4	4.0	49.6	7.00	0.57	--	0.70	0.52	--	
35	CO.041	26.0	6	150	159	260	450	2.0	20	47.9	0.95	33.1	3.9	58.7	4.32	0.64	--	0.75	0.52	--	
35	CO.041	26.0	7	174	183	260	450	2.0	20	49.7	1.24	30.9	4.4	61.3	3.50	0.66	--	0.71	0.49	--	
35	CO.041	26.0	8	198	206	240	450	2.0	20	19.6	0.55	17.3	2.6	79.1	0.93	0.71	--	2.08	1.63	--	

Feed Gas Rates

Per No	N ₂ SLH	H ₂ SLH	CO SLH	Total SLH
1	568	225	112	905
2	568	225	112	905
3	568	225	112	905
4	341	135	68	544
5	253	100	50	403
6	163	160	80	403
7	103	200	100	403
8	571	225	112	908

Table II

DATE: 12/30/94

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C6-18,%
					%C1	%C2	%C3+	%CO2			C3	C4	
5	CO.003	15.1	31.7	1.53	16.7	2.4	79.8	1.2	0.71	--	1.30	0.60	18.2
6	CO.011	15.3	14.3	0.67	7.6	1.6	89.4	1.4	0.78	0.83	4.17	2.57	21.7
7	CO.012	15.8	13.9	0.63	6.1	1.5	90.6	1.7	0.80	0.89	4.00	2.57	17.5
8	CO.015	15.0	28.3	1.37	12.7	2.0	84.1	1.2	0.76	0.80	1.61	1.07	19.6
9	CO.011	15.0	18.5	0.89	8.8	1.7	88.8	0.8	0.78	0.83	3.18	1.85	20.3
11	CO.017	15.0	27.2	1.32	11.2	1.8	85.9	1.1	0.77	0.80	2.09	1.20	30.8
12	CO.018	15.6	33.8	1.56	9.7	2.0	86.6	1.7	0.75	0.85	1.81	1.13	21.0
13	CO.016	14.7	26.4	1.31	(1)	1.7	89.3	0.7	0.78	0.81	2.00	1.41	21.7
14	CO.019	15.2	13.9	0.66	(2)	1.7	97.2	0.7	0.80	0.86	5.33	2.67	26.6
15	CO.005	14.7	27.1	1.34	7.9	1.6	89.7	0.8	0.79	0.82	2.30	1.38	23.1
16	CO.002	15.4	30.1	1.42	12.5	2.5	83.9	1.1	0.75	0.80	1.00	0.66	17.5
17	CO.025	15.6	26.6	1.24	10.7	2.1	86.4	0.8	0.76	0.82	2.25	1.47	21.7
18	CO.004	15.0	33.9	1.64	15.3	2.4	80.9	1.4	0.74	0.79	1.17	0.78	20.3
19	CO.021	15.6	23.2	1.08	9.4	2.0	88.0	0.7	0.77	0.82	2.56	1.54	20.3
20	CO.041	15.8	25.3	1.16	11.0	2.1	86.0	0.9	0.76	0.84	2.94	1.61	20.3
21	CO.014	15.1	8.5	0.40	8.3	3.5	85.8	2.4	0.74	0.83	2.75	1.67	17.5
22	CO.040	14.5	1.8	0.09	0.0	4.0	94.1	1.9	0.71	0.82	2.50	2.00	--
23	CO.047	15.8	28.2	1.29	7.7	1.5	89.3	1.5	0.79	0.84	3.14	1.69	24.5
24	CO.049	15.6	30.6	1.41	10.9	1.8	85.7	1.7	0.76	0.82	2.09	1.30	14.0
25	CO.047	15.6	28.1	1.30	8.8	1.6	88.1	1.5	0.78	0.85	2.93	1.88	25.9
26	CO.031	15.9	30.9	1.41	12.1	1.9	84.9	1.1	0.75	0.83	1.83	1.14	22.4
27	CO.029	15.9	28.3	1.27	8.3	1.6	87.9	2.2	0.77	0.84	3.40	2.20	27.3
28	COW.01	15.0	1.1	0.05	0.0	12.	83.9	4.2	0.58	--	3.33	2.50	--
29	CO.053	25.2	42.0	1.19	15.8	2.3	79.5	2.4	0.73	--	1.00	0.67	17.5
30	CO.053	29.6	41.8	1.02	22.6	2.9	71.5	3.1	0.66	0.77	0.99	0.65	19.6
31	CO.055	15.0	30.0	1.46	23.7	3.7	70.2	2.3	0.61	0.81	0.90	0.60	20.3
32	CO.044	16.4	20.9	0.93	6.7	1.9	90.8	0.6	0.77	0.83	3.42	2.17	23.1
33	CO.053	31.4	41.4	0.94	23.2	3.1	69.6	4.1	0.65	0.76	0.82	0.58	21.7
34	CO.060	15.6	31.4	1.46	14.0	2.3	82.2	1.5	0.75	0.79	1.61	1.00	23.1

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts For Runs 11 thru 20, and 23 thru 28
screened thru 150 x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x400 mesh.

(1) Weak TCD filaments in G.C. CH4 peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH4 peak undetected.

D12

Table II
(Continued)

DATE: 06/30/95

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities %C1	%C2	%C3+	%CO2	Alpha GC	Alpha Liq	Olefin/Paraf C3	C4	Olefins C6-18,%
-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
35	Co.041	26.0	35.7	1.00	13.6	2.1	82.9	1.4	0.79	0.76	1.09	0.74	18.2
36	Co.032	15.9	24.0	1.10	9.1	1.8	88.2	0.8	0.77	0.83	3.23	2.00	25.2
37	Co.045	15.9	14.8	0.67	8.0	1.7	89.4	0.9	0.76	0.84	2.78	1.90	20.3
38	Co.058	15.9	28.0	1.28	11.9	2.1	85.1	0.9	0.75	0.85	1.88	1.17	22.4
39	Co.064	15.9	34.2	1.56	13.6	2.3	82.6	1.6	0.73	0.85	1.40	0.92	21.0
40	Co.063	15.0	8.7	0.43	6.5	0.9	92.6	0.1	0.74	--	7.67	3.40	25.9
41	Co.062	15.0	6.6	0.32	3.5	0.3	95.3	1.0	0.76	0.89	9.50	3.50	25.9
42	Co.065	15.9	27.6	1.25	7.9	2.0	88.6	1.6	0.79	0.84	2.94	1.88	28.0
43	COW.12	9.1	6.1	0.47	20.3	6.1	66.3	7.3	0.61	0.83	3.63	2.33	11.9
44	COW.11	15.6	4.7	0.20	8.4	6.3	74.4	10.9	0.60	--	5.40	3.50	--
45	Fe.01	15.9	3.4	0.14	0.0	7.5	84.8	7.7	0.71	0.77	2.80	1.50	--
46	COW.05	15.7	4.9	0.23	10.9	6.5	81.9	0.7	0.60	0.78	3.11	2.14	13.3
47	Co.070	15.6	22.8	1.07	10.9	2.7	85.7	0.70	0.75	0.85	2.60	1.56	24.5

Note: All catalysts were screened thru 150 x 400 mesh.

Catalyst No. COW.12 contains 10% Co plus 10% Fe. It is also full size.

Catalyst No. Fe.01 contains 30% Fe and no cobalt.

Catalyst No. Co.070 contains 13% Co with no promoter.

Table III

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
2	220 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N₂-563 SLH, H₂-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefin
					%CH4	%C2	%C3+	%CO2			C3	C4	C6-18,
5	CO.003	15.1	13.2	0.63	5.1	1.0	93.4	0.5	0.82	0.90	4.55	1.89	--
6	CO.011	15.3	5.1	0.23	0.0	0.0	97.2	2.8	0.87	0.82	--	--	--
7	CO.012	15.8	5.1	0.23	0.0	0.2	97.8	2.0	0.89	0.90	--	2.50	--
8	CO.015	15.0	11.5	0.56	4.4	1.0	93.9	0.8	0.81	0.89	3.60	2.14	--
9	CO.011	15.0	6.3	0.31	0.0	1.0	98.6	0.4	0.88	0.93	12.00	1.80	--
11	CO.017	15.0	11.4	0.55	5.0	0.0	94.8	0.2	0.88	0.90	5.00	3.20	--
12	CO.018	15.6	12.6	0.59	2.8	0.0	97.1	0.1	0.90	0.88	--	--	--
13	CO.016	14.7	9.7	0.48	(1)	0.1	99.9	0.0	0.91	0.88	--	--	--
14	CO.019	15.2	3.8	0.18	(2)	1.7	96.7	1.6	0.88	--	--	--	--
15	CO.005	14.7	10.7	0.53	0.0	0.9	98.4	0.7	0.83	0.88	4.25	3.25	--
16	CO.002	15.4	12.8	0.60	4.2	1.3	93.9	0.7	0.80	0.86	2.57	1.63	--
17	CO.025	15.6	8.4	0.39	0.0	1.1	96.9	1.9	0.82	0.92	6.50	3.00	--
18	CO.004	15.0	15.1	0.73	4.1	1.6	94.0	0.3	0.81	0.85	3.83	2.25	--
19	CO.021	15.6	8.3	0.38	0.0	1.3	98.2	0.5	0.82	0.88	4.33	3.33	--
20	CO.041	15.8	9.1	0.41	0.0	1.5	97.8	0.7	0.82	0.91	8.00	2.75	--
21	CO.014	15.1	3.2	0.15	0.0	2.3	85.8	4.3	0.76	0.86	3.50	3.00	--
22	CO.040	14.5	0.7	0.35	0.0	0.7	97.1	2.2	0.91	--	1.00	2.00	--
23	CO.047	15.8	---	---	(3)	---	---	---	---	---	---	---	--
24	CO.049	15.6	12.0	1.07	2.7	0.9	95.3	1.1	0.81	0.95	4.25	3.25	--
25	CO.047	15.6	7.4	0.34	1.5	1.2	96.3	1.0	0.76	0.89	3.00	4.67	--
26	CO.031	15.9	13.6	0.62	3.9	0.9	94.6	0.5	0.80	0.85	4.20	2.67	--
27	CO.029	15.9	9.5	0.43	1.7	1.1	96.0	1.2	0.80	0.89	5.67	3.00	--
29	CO.053	25.2	20.5	0.59	5.7	4.8	89.0	0.5	0.79	0.84	3.38	2.10	--
31	CO.055	15.0	9.1	0.44	10.6	2.5	85.7	1.1	0.61	0.85	2.89	1.80	--
32	CO.044	16.4	10.3	0.46	0.0	0.9	98.8	0.3	0.85	--	4.33	4.50	--
34	CO.060	15.6	13.0	0.60	0.1	1.8	97.8	0.4	0.81	0.88	4.00	2.83	--

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts for Runs 11 thru 27 (except Runs 21 and 22) screened through 150 x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x 400.

(1) Weak TCD filaments in G.C. CH₄ peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH₄ peak undetected.

(3) Replaced dual column restrictor valve.

Table III
(Continued)

DATE: 06/30/95

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
2	220 C	450psi	2.0

- a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.
Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH
b) Conversion is total CO conversion over the period (%).
c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.
d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)
e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefin
					%CH4	%C2	%C3+	%CO2			C3	C4	C6-18,
----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
36	Co.032	15.9	7.7	0.35	0.0	1.5	97.8	0.77	0.81	0.91	4.00	3.33	--
37	Co.045	15.9	5.1	0.23	0.0	1.5	97.7	0.77	0.80	0.88	4.00	3.00	--
38	Co.058	15.9	11.7	0.54	1.4	1.4	96.9	0.38	0.81	--	4.00	3.00	--
39	Co.064	15.9	15.0	0.68	4.6	1.2	93.8	0.44	0.78	--	4.17	2.38	--
40	Co.063	15.0	2.0	0.09	0.1	0.0	99.9	0.00	0.67	--	7.00	7.00	--
41	Co.062	15.0	1.9	0.09	0.0	0.1	99.9	0.00	0.88	--	4.00	5.00	--
42	Co.065	15.9	10.0	0.46	0.0	2.0	97.3	0.67	0.82	--	5.33	3.25	--
47	Co.070	15.6	8.6	0.40	0.0	4.3	95.7	0.02	0.82	--	--	--	--

Note: All catalysts were screened thru 150 x 400 mesh.

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
4	240 C	450psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefin C6-18,
					%CH4	%C2	%C3+	%CO2			C3	C4	
5	CO.003	15.1	13.1	0.95	4.2	1.2	93.3	1.2	0.83	0.88	6.67	3.70	--
6	CO.011	15.3	6.3	0.44	0.4	1.0	95.5	3.1	0.82	0.88	--	--	--
7	CO.012	15.8	3.9	0.26	4.8	2.3	86.3	6.6	0.70	0.85	16.00	3.50	--
8	CO.015	15.0	11.5	0.83	4.8	1.2	92.5	1.5	0.80	0.85	5.60	3.29	--
9	CO.011	15.0	8.0	0.58	1.3	1.3	96.3	1.2	0.82	0.87	7.00	2.83	--
11	CO.017	15.0	11.6	0.84	5.0	0.0	93.9	1.2	0.82	0.86	25.00	2.88	--
12	CO.018	15.6	12.4	0.86	3.3	0.0	95.0	1.7	0.80	0.86	--	--	--
13	CO.016	14.7	10.9	0.81	(1)	0.8	97.7	0.3	0.84	0.86	--	--	--
14	CO.019	15.2	--	--	(2)	--	--	--	0.80	--	--	--	--
15	CO.005	14.7	11.6	0.85	0.0	1.1	97.5	1.4	0.82	0.85	7.00	4.60	--
16	CO.002	15.4	12.6	0.89	4.4	1.6	92.8	1.2	0.79	0.84	4.43	2.88	--
17	CO.025	15.6	10.3	0.71	0.8	1.2	96.7	1.3	0.82	0.93	7.67	4.25	--
18	CO.004	15.0	14.7	1.06	4.1	1.2	93.2	1.4	0.80	0.83	6.17	3.75	--
19	CO.021	15.6	9.9	0.69	1.7	1.4	95.5	1.4	0.81	0.83	6.00	3.80	--
20	CO.041	15.8	12.7	0.88	1.9	1.2	95.9	1.0	0.83	0.86	9.00	4.20	--
21	CO.014	15.1	2.2	0.15	0.0	2.8	89.3	7.9	0.67	0.84	9.00	4.00	--
23	CO.047	15.8	11.9	0.81	2.9	0.9	94.1	2.1	0.82	0.88	7.33	4.75	--
24	CO.049	15.6	12.6	0.87	3.1	1.0	94.1	1.8	0.81	0.86	8.33	4.20	--
25	CO.047	15.6	10.8	0.75	3.0	1.0	94.2	1.8	0.81	0.90	8.00	4.75	--
26	CO.031	15.9	12.9	0.88	3.6	1.1	94.3	1.1	0.80	0.88	7.75	4.00	--
27	CO.029	15.9	12.0	0.82	1.9	0.9	95.4	1.9	0.83	0.90	8.33	4.75	--
29	CO.053	25.2	18.4	0.79	5.3	2.6	90.6	1.5	0.80	0.84	5.86	3.56	--
31	CO.055	15.0	14.7	1.06	5.5	1.4	91.7	1.4	0.78	0.83	5.71	3.22	--
32	CO.044	16.4	9.9	0.25	2.1	3.2	92.5	2.2	0.61	0.87	7.33	4.00	--
34	CO.060	15.6	13.5	0.94	4.3	1.8	92.5	1.5	0.77	0.85	7.00	4.67	--

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts for Runs 11 thru 20 and Run 27 (except Runs 21 and 22)

screened thru 150 x 400 mesh.

Catalysts for Runs 21 and 22 screened thru 100 x 400 mesh.

(1) Weak TCD filaments in G.C. CH4 peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH4 peak undetected.

Table IV
(Continued)

DATE: 06/30/95

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
4	240 C	450psi	1.0

- a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.
 Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH
 b) Conversion is total CO conversion over the period (%).
 c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.
 d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)
 e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefin C6-18,
---	---	---	---	---	%CH4	%C2	%C3+	%CO2	---	---	C3	C4	---
36	Co.032	15.9	9.5	0.65	1.4	1.2	96.5	0.87	0.83	--	7.67	4.50	--
37	Co.045	15.9	6.5	0.44	0.1	1.4	97.3	1.16	0.82	--	5.00	2.00	--
38	Co.058	15.9	12.7	0.87	3.2	1.3	94.5	1.01	0.81	--	7.25	4.40	--
39	Co.064	15.9	15.9	1.09	4.7	1.2	92.9	1.28	0.80	--	7.86	3.88	--
40	Co.063	15.0	3.6	0.26	2.3	1.3	95.9	0.54	0.76	--	13.00	5.50	--
41	Co.062	15.0	2.7	0.19	0.1	1.0	96.9	1.99	0.77	--	10.00	4.00	--
42	Co.065	15.9	13.1	0.89	1.2	1.5	95.7	1.67	0.84	--	7.00	5.50	--
47	Co.070	15.6	5.3	0.37	3.7	4.2	90.3	1.76	0.71	--	2.85	1.71	--

Note: All catalysts were screened thru 150 x 400 mesh.

Table V

DATE: 12/30/94

M3 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
5	240 C	600psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr)

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin C3	Paraf C4	Olefin C6-18,%
-----	-----	-----	-----	-----	%CH4	%C2	%C3+	%CO2	-----	-----	-----	-----	-----
5	CO.003	15.1	13.4	0.97	3.9	1.1	93.7	1.3	0.81	--	5.26	3.45	30.1
6	CO.011	15.3	6.7	0.46	0.2	0.9	96.0	2.9	0.84	0.89	12.00	3.67	27.3
7	CO.012	15.8	4.3	0.28	0.1	2.1	91.6	6.3	0.75	0.82	8.50	3.50	--
8	CO.015	15.0	12.4	0.90	4.9	0.8	93.6	0.7	0.84	0.85	5.20	3.14	30.8
9	CO.011	15.0	8.7	0.63	1.4	1.1	96.4	1.1	0.83	0.87	5.00	2.67	30.5
11	CO.017	15.0	11.6	0.84	4.2	0.0	94.7	1.2	0.86	0.86	24.00	1.63	21.0
12	CO.018	15.6	13.0	0.90	3.2	0.0	94.9	1.9	0.80	0.85	--	--	38.5
13	CO.016	14.7	11.4	0.85	(1)	0.5	99.2	0.3	0.92	0.86	--	--	32.2
14	CO.019	15.2	5.9	0.41	(2)	1.5	96.1	2.4	0.80	--	--	--	--
15	CO.005	14.7	23.0	0.90	0.0	1.0	97.7	1.3	0.83	0.85	7.00	4.40	36.4
16	CO.002	15.4	13.1	0.92	3.6	1.4	93.9	1.1	0.81	0.84	4.29	2.75	25.2
17	CO.025	15.6	19.9	0.81	9.3	1.1	96.5	1.1	0.83	0.88	8.00	4.25	32.9
18	CO.004	15.0	15.0	1.09	3.6	1.1	94.1	1.2	0.82	0.83	5.67	4.00	33.6
19	CO.021	15.6	11.5	0.80	1.8	1.2	95.8	1.2	0.83	0.85	6.50	3.80	30.8
20	CO.041	15.8	13.2	0.91	2.0	1.0	96.1	0.9	0.84	0.87	7.00	3.50	31.5
21	Co.014	15.1	2.1	0.15	0.0	2.6	94.8	2.7	0.71	0.81	4.50	3.50	23.1
23	CO.047	15.8	11.8	0.80	2.6	0.8	94.6	2.0	0.82	0.87	7.00	3.60	38.5
24	CO.049	15.6	13.4	0.92	2.6	0.9	94.8	1.7	0.82	0.88	8.33	4.20	37.8
25	CO.047	15.6	12.4	0.86	2.2	0.8	95.6	1.3	0.83	0.86	7.33	4.50	36.4
26	CO.031	15.9	13.9	0.95	3.5	1.0	94.4	1.1	0.81	0.85	6.80	3.71	30.1
27	CO.029	15.9	12.1	0.82	1.7	0.9	95.6	1.8	0.83	0.89	7.67	4.75	39.9
29	CO.053	25.2	19.7	0.85	4.6	1.2	92.9	1.3	0.82	0.85	5.71	3.44	33.6
31	CO.055	15.0	16.1	1.16	4.7	1.2	92.8	1.3	0.80	0.83	6.17	3.11	33.6
34	CO.060	15.6	12.8	0.89	2.2	1.6	94.9	1.2	0.82	0.86	6.60	4.33	38.5

Note: Catalyst Run 9 screened thru 170 x 400 mesh.

Catalysts for Runs 11 thru 27 (except Runs 21 and 22) screened thru 150 x 400 mesh.

Catalyst for Run 21 screened thru 100 x 400 mesh.

(1) Weak TCD filaments in G.C. CH4 peaks smaller than expected.

(2) Internal valve in G.C. leaked. CH4 peak undetected.

Table VI
(Continued)

SUMMARY OF M4 SBGR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min, STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using M2 as an internal

standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run Cat. Cat. Per Time Time Temp Pres M2: Syntl Conv. Prod. Selectivities Alpha Alpha Olefin/Paraf Olefins Comments
No No wt,g No Start Stop C psi CO cc/hr % Rate %C₁+ %C₂ %C₃+ %C₄ GC Liq C₃ C₄ C₆-18, %

9 CO.048 15.4	1	19	40	240	450	2.0	12	19.1	0.90	9.9	1.6	87.4	1.05	0.77	0.88	3.60	2.09	20.3	--
9 CO.048 15.4	2	70	84	220	450	2.0	12	6.1	0.28	1.8	1.0	95.2	1.93	0.80	0.91	3.67	3.00	--	--
9 CO.048 15.4	3	93	111	240	450	2.0	20	17.8	0.84	10.1	1.7	86.9	1.33	0.77	--	3.30	2.10	--	--
9 CO.048 15.4	4	139	159	240	450	1.0	20	8.2	0.57	2.3	1.0	93.8	2.98	0.82	0.90	8.50	4.33	--	--
9 CO.048 15.4	5	189	207	240	600	1.0	20	11.9	0.83	2.7	0.9	94.4	1.93	0.84	0.89	5.75	3.20	--	14.0
9 CO.048 15.4	6	217	226	240	450	2.0	20	26.2	1.17	17.1	3.1	79.0	0.83	0.71	--	1.03	0.70	--	--
10 CAL.02 15.9	1	19	40	240	450	2.0	20	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.84	1.66	1.06	21.0	--
10 CAL.02 15.9	2	69	88	220	450	2.0	20	14.9	0.68	4.6	0.9	94.0	0.47	0.81	0.88	4.40	2.29	--	--
10 CAL.02 15.9	3	91	112	240	450	2.0	20	34.2	1.57	12.6	2.0	84.4	1.00	0.75	--	1.71	1.06	--	--
10 CAL.02 15.9	4	139	160	240	450	1.0	20	14.6	1.00	4.6	1.1	93.3	0.97	0.80	0.88	7.20	4.00	--	--
10 CAL.02 15.9	5	187	201	240	600	1.0	20	16.4	1.12	4.2	1.0	94.0	0.89	0.82	0.86	5.83	3.86	35.7	--
10 CAL.02 15.9	6	215	230	240	450	2.0	20	30.9	1.42	13.3	2.1	83.7	0.90	0.74	--	1.90	1.21	--	--
11 CAL.03 15.6	1	19	40	240	450	2.0	20	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	1.65	1.03	18.2	Shutdown
12 CO.053 15.9	1	22	40	240	450	2.0	20	34.2	1.56	12.6	2.0	84.2	1.23	0.75	0.83	1.60	1.00	24.5	--
12 CO.053 15.9	2	69	88	220	450	2.0	20	14.4	0.66	4.3	1.0	94.3	0.48	0.81	0.89	4.20	2.67	--	--
12 CO.053 15.9	3	93	112	240	450	2.0	20	34.0	1.56	13.4	2.2	83.2	1.21	0.74	--	1.50	0.94	--	--
12 CO.053 15.9	4	150	152	240	450	1.0	20	13.3	0.91	4.3	1.2	93.3	1.18	0.80	0.89	6.60	3.71	--	--
12 CO.053 15.9	5	189	208	240	600	1.0	20	15.6	1.06	4.0	0.9	94.0	1.01	0.82	0.87	5.50	3.57	32.2	--
12 CO.053 15.9	6	223	231	240	450	2.0	20	29.8	1.37	12.8	2.0	84.3	0.94	0.75	--	1.89	1.10	--	--
13 CO.054 15.7	1	23	40	240	450	2.0	20	10.4	0.48	4.7	1.8	92.3	1.17	0.78	0.86	5.75	4.00	25.9	--
13 CO.054 15.7	2	71	88	220	450	2.0	20	0.2	0.01	0.0	19.6	0.8	19.5	0.33	0.94	8.00	5.00	--	--
13 CO.054 15.7	3	102	112	240	450	2.0	20	10.6	0.49	4.5	1.5	92.8	1.23	0.79	--	5.50	3.75	--	--
13 CO.054 15.7	4	143	160	240	450	1.0	20	5.2	0.36	0.0	1.2	97.0	1.85	0.83	0.95	6.00	4.50	--	--
13 CO.054 15.7	5	191	208	240	600	1.0	20	5.0	0.34	0.0	1.3	96.9	1.78	0.82	0.93	6.50	3.33	30.8	--
13 CO.054 15.7	6	223	230	240	450	2.0	20	8.8	0.40	4.7	2.0	91.7	1.54	0.78	--	5.00	3.50	--	--
14 BlendA 20.0	1	25	39	240	450	2.0	20	29.3	1.41	10.1	1.6	86.3	2.02	0.77	0.86	2.23	1.35	23.1	--
14 BlendA 20.0	2	69	87	220	450	2.0	20	12.4	0.60	4.3	0.9	93.9	0.95	0.81	0.91	3.80	2.33	--	--
14 BlendA 20.0	3	93	111	240	450	2.0	20	27.5	1.33	10.5	1.7	86.4	1.44	0.76	--	2.09	1.32	--	--
14 BlendA 20.0	4	143	158	240	450	1.0	20	12.7	0.91	3.4	1.0	94.0	1.61	0.81	0.86	7.50	3.83	--	--
14 BlendA 20.0	5	191	207	240	600	1.0	20	14.1	1.02	3.7	1.0	93.8	1.45	0.82	0.89	6.40	3.43	32.9	--
14 BlendA 20.0	6	215	231	240	450	2.0	20	27.0	1.29	11.5	1.9	85.5	1.12	0.76	--	2.04	1.30	--	--

SUMMARY OF M4 SECR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (2).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Per wt. g	Time No	Time Start	Temp Stop	Pres C	H2: psi	Synfl CO	Conv. cc/hr	Prod. %	Rate	Selectivities	Alpha GC	Alpha Liq	Olefin/Paraf C3	Olefins C4	Comments
												IC4 IC2 IC3+ IC02					
15	CO.034	13.0	1	21	39	240	450	2.0	20	27.5	1.54	10.4 1.6 87.2 0.80	0.78	0.84	2.21	1.40	21.0 G.C. Calib
15	CO.034	13.0	2	45	87	220	450	2.0	20	11.0	0.61	4.0 0.9 94.5 0.59	0.82	0.90	4.00	3.00	--
15	CO.034	13.0	3	95	111	240	450	2.0	20	26.6	1.49	11.5 1.9 85.9 0.82	0.76	--	2.10	1.33	--
15	CO.034	13.0	4	141	159	240	450	1.0	20	11.2	0.94	3.9 1.0 94.0 1.02	0.82	0.87	8.33	4.00	--
15	CO.034	13.0	5	189	207	240	600	1.0	20	11.8	0.99	3.9 1.1 94.0 1.03	0.83		5.75	3.80	37.8
15	CO.034	13.0	6	215	231	240	450	2.0	20	21.6	1.19	10.9 1.9 86.3 0.87	0.76	--	3.33	2.15	--
16	CAL.04	16.1	1	21	39	240	450	1.8	20	26.3	1.34	7.1 1.3 90.3 1.38	0.80	0.85	4.80	3.18	32.9 H2/CO:
16	CAL.04	16.1	2	54	163	220	450	1.8	20	8.4	0.42	2.6 1.0 94.1 2.31	0.80	0.88	5.00	4.00	-- 1.76/1.0
17	CAL.08	15.0	1	21	39	240	450	1.8	20	16.9	0.93	5.9 1.0 91.7 1.36	0.82	0.88	5.20	3.33	28.7 H2/CO:
17	CAL.08	15.0	2	47	62	220	450	1.8	20	5.4	0.28	0.1 0.8 96.9 2.23	0.83	--	4.00	3.00	-- 1.76/1.0
18	CAL.07	15.0	1	21	39	240	450	2.0	20	20.6	1.03	7.7 1.2 90.0 1.09	0.81	0.88	5.00	3.00	32.2
18	CAL.07	15.0	2	47	62	220	450	2.0	20	6.7	0.33	1.8 1.4 95.0 1.81	0.84	--	4.00	3.00	--
19	CAL.05	15.7	1	23	39	240	450	2.0	20	26.6	1.22	7.3 1.3 90.2 1.19	0.82	0.86	4.11	2.70	18.2 G.C. Calib
19	CAL.05	15.7	2	47	62	220	450	2.0	20	9.0	0.41	2.3 1.4 94.8 1.56	0.84	--	5.50	3.00	--
20	CAL.06	15.0	1	15	30	240	450	2.0	20	5.6	0.26	3.1 2.1 92.0 2.86	0.80	0.90	4.50	3.50	30.8 G.C. Calib
20	CAL.06	15.0	2	55	63	240	450	2.0	20	3.5	0.16	0.0 3.3 92.8 3.87	0.80	0.85	3.00	2.50	--
20	CAL.06	15.0	3	103	110	240	450	2.0	20	1.7	0.08	0.0 3.3 89.5 7.22	0.80	--	1.50	3.00	-- Cat. Loss
21	CO.004	15.9	1	23	40	240	450	2.0	20	39.3	1.80	15.2 2.3 81.2 1.38	0.74	0.89	1.16	0.73	23.1
21	CO.004	15.9	2	71	88	220	450	2.0	20	16.1	0.74	8.1 1.2 90.2 0.48	0.78	0.87	3.38	2.22	--
21	CO.004	15.9	3	105	110	240	450	2.0	20	37.6	1.47	16.4 2.3 80.2 1.20	0.73	--	1.10	0.70	--
21	CO.004	15.9	4	136	138	240	450	1.0	20	14.9	1.02	7.4 1.4 89.9 1.29	0.77	0.84	4.67	2.82	--
21	CO.004	15.9	5	166	184	240	600	1.0	20	18.4	1.26	6.1 1.1 91.9 0.94	0.81	0.84	5.25	2.91	-- G.C. Repair
21	CO.004	15.9	6	199	207	240	600	2.0	20	39.0	1.80	14.2 1.9 83.0 0.91	0.78	0.82	0.85	0.77	--
21	CO.004	15.9	7	212	214	240	450	2.0	20	34.6	1.59	15.8 2.3 81.0 1.00	0.76	--	0.86	0.81	-- G.C. Repair
22	BlendB	30.5	1	23	39	240	450	2.0	20	35.6	1.64	12.7 1.6 79.4 6.29	0.75	0.81	1.40	0.81	27.3
22	BlendB	30.5	2	78	87	240	450	1.0	20	15.8	1.07	1.5 0.9 90.5 7.06	0.80	0.83	5.00	2.22	38.5 G.C. Calib
22	BlendB	30.5	3	125	135	240	450	0.7	20	10.6	0.86	0.8 0.8 92.6 5.83	0.82	0.87	7.33	3.20	33.6 G.C. Calib
22	BlendB	30.5	4	150	158	240	450	1.0	20	14.1	0.99	3.9 1.0 91.0 4.07	0.80	--	5.40	2.25	--
22	BlendB	30.5	5	174	183	240	450	2.0	20	30.1	1.44	13.2 1.8 82.4 2.56	0.75	--	1.33	0.69	--
22	BlendB	30.5	6	191	207	260	450	1.0	20	23.5	1.63	10.0 1.9 82.1 6.02	0.74	--	2.92	1.15	--
22	BlendB	30.5	7	223	232	280	450	1.0	20	26.9	1.79	17.8 3.1 68.4 10.7	0.64	--	3.00	1.88	--
22	BlendB	30.5	8	247	255	280	450	0.7	20	17.1	1.34	8.8 2.6 78.8 9.8	0.70	--	6.00	3.53	--
23	CAL.09	15.0	1	23	40	240	450	2.0	20	17.4	0.84	0.02 1.2 97.9 0.95	0.84	0.88	5.40	3.33	29.4 G.C. Calib
23	CAL.09	15.0	2	57	63	220	450	2.0	20	6.6	0.32	0.2 0.9 98.0 0.92	0.90	--	4.00	3.00	--

Table VI
(Continued)

SUMMARY OF M4 SBGA RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.
b) Conversion is total CO conversion over the period (2).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run Cate. Calc. Per Time Temp Pres H2: Synth Conv. Prod. Selectivities Alpha Alpha Olefin/Parad Olefins Comments
No No wt.% No Start Stop C psi CO cc/hr I Rate ICH4 ICH2 ICH3+ ICH2 GC L19 C3 C4 C5-18.1

24	CO,053	28.5	1	23	39	240	450	2.0	20	50.4	1.28	14.1	2.1	81.8	2.03	0.75	0.79	1.14	0.68	--	G.C.Calib
24	CO,053	28.5	2	54	63	250	450	2.0	20	53.5	1.34	24.2	3.6	67.9	4.24	0.66	--	0.66	0.48	--	
24	CO,053	28.5	3	78	87	260	450	2.0	30	55.3	1.36	38.2	5.2	49.0	7.64	0.53	--	0.53	0.47	--	
24	CO,053	28.5	4	102	110	260	450	2.0	30	52.8	2.13	29.1	4.0	62.1	4.79	0.64	--	0.64	0.49	--	
24	CO,053	28.5	5	126	135	260	450	2.0	30	58.9	1.90	28.5	3.9	62.8	4.90	0.65	--	0.70	0.48	--	
24	CO,053	28.5	6	146	158	260	450	2.0	30	42.6	1.74	26.9	3.8	66.3	2.96	0.65	--	0.99	0.67	--	
24	CO,053	28.5	7	175	182	260	450	2.0	30	51.5	1.31	31.6	4.5	60.0	3.90	0.60	--	0.94	0.65	--	
24	CO,053	28.5	8	199	208	260	450	2.0	30	58.1	1.89	27.6	3.7	65.1	3.67	0.66	--	0.88	0.56	--	
24	CO,053	28.5	9	218	231	260	450	2.0	30	62.9	2.05	23.2	3.0	70.6	3.20	0.71	--	0.93	0.58	--	
24	CO,053	28.5	10	259	263	275	450	2.0	30	72.1	2.24	39.1	5.0	46.4	9.53	0.57	--	0.41	0.34	--	
24	CO,053	28.5	11	290	304	260	450	2.0	30	48.8	1.62	29.0	3.8	65.4	1.83	0.65	--	1.78	1.09	--	

Feed Gas Rates
Per N2 H2 CO Total
No SLR SLR SLR SLR

1	563	225	112	900
2	563	225	112	900
3	563	225	112	900
4	360	360	180	900
5	288	288	144	720
6	540	360	180	1080
7	563	225	112	900
8	200	288	144	632
9	108	288	144	540
10	108	288	144	540
11	108	288	144	540

Table VI
(Continued)

SUMMARY OF M4 SECR RUN RESULTS

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (2).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Per wt.,g	Time No	Time Start	Temp Stop	Pres C	H2: Synfl psi CO	Conv. Prod. I Rate	Selectivities ICH4	IC2	IC3+	IC32	Alpha GC	Alpha Liq	Olefin/Paraf C3	Olefins C4	Comments C5-18,2
26	CAL.10	15.6	1	23	39	240	450 2.0	20 21.9 1.01	5.4	1.5	91.9	1.25	0.79	0.85	3.60	2.27	25.9
26	CAL.10	15.6	2	54	63	240	450 2.0	20 21.7 1.30	8.3	1.1	89.9	1.10	0.80	--	3.78	2.45	--
26	CAL.10	15.6	3	78	87	240	450 2.0	20 17.2 1.04	11.7	1.4	86.1	1.39	0.76	--	3.57	2.30	--
26	CAL.10	15.6	4	102	111	240	450 2.0	20 17.7 1.01	11.9	1.4	86.0	1.40	0.77	--	3.52	2.28	--
26	CAL.10	15.6	5	118	126	240	450 2.0	20 16.2 0.75	4.9	1.7	92.3	1.10	0.77	--	4.29	2.75	--

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
1	563	225	112	900
2	108	288	144	540
3	54	288	144	486
4	25	274	137	436
5	563	225	112	900

Table VI
(Continued)

SUMMARY OF M4 SECR RUN RESULTS

a)Unless otherwise noted, total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b)Conversion is total CO conversion over the period (X).

c)Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d)Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr).

e)Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C5-18,2	Comments
												XCH4	XC2	XC3+	XCO2			C3	C4		
25	CO.056	15.0	1	23	39	240	450	2.0	20	11.4	0.55	7.8	3.6	87.2	1.43	0.67	0.87	3.60	2.30	20.3	
25	CO.056	15.0	2	47	63	220	450	2.0	20	4.5	0.22	0.3	2.7	95.7	1.27	0.73	--	4.67	3.00	--	
26	CAL.10	15.6	1	23	39	240	450	2.0	20	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	3.60	2.27	25.9	
26	CAL.10	15.6	2	54	63	240	450	2.0	20	21.7	1.30	8.3	1.1	89.9	0.68	0.80	--	3.78	2.45	--	
26	CAL.10	15.6	3	78	87	240	450	2.0	20	17.2	1.04	11.7	1.4	86.1	0.78	0.76	--	3.57	2.30	--	
26	CAL.10	15.6	4	102	111	240	450	2.0	20	17.7	1.01	11.9	1.4	86.0	0.73	0.77	--	3.52	2.28	--	
26	CAL.10	15.6	5	118	126	240	450	2.0	20	16.2	0.75	4.9	1.7	92.3	1.10	0.77	--	4.29	2.75	--	
27	Co.050	14.6	1	23	39	240	450	2.0	20	20.4	1.01	6.8	1.9	90.2	1.04	0.78	0.87	2.50	1.69	18.9	
27	Co.050	14.6	2	78	87	220	450	2.0	20	8.1	0.39	0.0	4.8	92.6	2.56	0.79	0.87	8.50	3.00	--	
27	Co.050	14.6	3	102	111	240	450	2.0	20	19.8	0.98	9.1	2.6	87.0	1.30	0.76	--	2.50	1.69	--	
27	Co.050	14.6	4	142	157	240	450	1.0	20	8.4	0.61	1.1	2.9	93.3	2.78	0.79	0.90	6.25	5.00	--	
27	Co.050	14.6	5	173	182	240	450	2.0	20	17.3	0.87	9.9	3.0	85.4	1.74	0.75	--	2.50	1.75	--	
28	Co.057	15.8	1	23	40	240	450	2.0	20	18.7	0.86	5.3	1.5	92.3	0.98	0.81	0.85	3.27	2.36	23.1	
28	Co.057	15.8	2	71	88	220	450	2.0	20	6.0	0.27	0.0	1.9	97.2	0.93	0.79	--	5.50	4.00	--	G.C.Repair
28	Co.057	15.8	3	102	112	240	450	2.0	20	19.4	0.90	7.7	2.1	89.3	0.97	0.77	--	3.70	2.27	--	
28	Co.057	15.8	4	126	135	240	450	1.0	20	8.1	0.56	1.3	4.6	92.7	1.44	0.79	--	7.33	5.67	--	
28	Co.057	15.8	5	150	159	240	450	2.0	20	18.0	0.83	7.6	3.3	88.0	1.00	0.76	--	3.89	2.30	--	
28	Co.057	15.8	6	175	184	250	450	2.0	20	25.3	1.16	13.2	2.8	82.5	1.60	0.73	--	2.30	1.45	--	
28	Co.057	15.8	7	198	208	260	450	2.0	20	29.7	1.36	22.7	3.9	70.7	2.75	0.65	--	1.39	0.92	--	
28	Co.057	15.8	8	222	231	240	450	2.0	20	13.8	0.63	8.7	2.6	87.4	1.34	0.75	--	3.11	2.11	--	
29	Co.061	45.4	1	39	41	240	450	2.0	20	29.0	0.46	14.4	2.6	81.6	1.53	0.72	0.80	1.49	0.94	18.9	G.C.Calib
29	Co.061	45.4	2	54	64	220	450	2.0	20	11.8	0.19	3.9	1.9	93.5	0.73	0.77	--	3.67	2.29	--	Cat.Loss
29	Co.061	45.4	3	78	86	240	450	2.0	20	24.4	0.39	13.3	2.5	83.2	1.08	0.72	--	1.67	1.08	--	Cat.Loss
30	Co.011	15.9	1	23	40	240	450	2.0	20	8.0	0.36	5.8	3.9	87.8	2.49	0.71	0.89	5.75	3.00	22.4	G.C.Repair
30	Co.011	15.9	2	54	64	250	450	2.0	20	15.8	0.72	10.0	3.0	84.8	2.28	0.74	--	4.22	2.40	--	
30	Co.011	15.9	3	78	87	260	450	2.0	20	23.6	1.06	18.1	3.7	74.5	3.72	0.67	--	2.21	1.54	--	G.C.Repair
30	Co.011	15.9	4	102	111	270	450	2.0	20	28.3	1.26	26.5	3.4	64.9	5.23	0.60	--	1.67	1.14	--	
30	Co.011	15.9	5	126	135	278	450	2.0	20	28.5	1.27	34.5	4.0	55.1	6.43	0.53	--	1.84	1.26	--	
30	Co.011	15.9	6	150	159	280	450	2.0	20	36.0	0.95	40.3	4.5	47.9	7.32	0.48	--	1.77	1.20	--	
30	Co.011	15.9	7	174	183	280	450	2.0	20	38.5	0.77	43.7	4.7	43.7	7.90	0.45	--	1.93	1.29	--	
30	Co.011	15.9	8	198	207	280	450	2.0	20	36.0	1.15	38.5	4.5	50.9	6.07	0.52	--	2.18	1.43	--	
30	Co.011	15.9	9	222	230	240	450	2.0	20	4.4	0.20	6.9	4.0	85.5	3.63	0.66	--	6.00	3.67	--	

Table VI
(Continued)

SUMMARY OF M4 SBCR RUN RESULTS

a)Unless otherwise noted, total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b)Conversion is total CO conversion over the period (X).

c)Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d)Prod. rate: Rate for production of total hydrocarbons, C1+ (kg/kg cat.,hr).

e)Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt.,g	Per No	Time Start	Time Stop	Temp C	Pres psi	H2: CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		Olefins C5-18,X	Comments
												XCH4	XC2	XC3+	XCO2			C3	C4		
30	Co.011	15.9	1	23	40	240	450	2.0	20	8.0	0.36	5.8	3.9	87.8	2.49	0.71	0.89	5.75	3.00	22.4	G.C.Calib
30	Co.011	15.9	2	54	64	250	450	2.0	20	15.8	0.72	10.0	3.0	84.8	2.28	0.74	--	4.22	2.40	--	
30	Co.011	15.9	3	78	87	260	450	2.0	20	23.6	1.06	18.1	3.7	74.5	3.72	0.67	--	2.21	1.54	--	
30	Co.011	15.9	4	102	111	270	450	2.0	20	28.3	1.26	26.5	3.4	64.9	5.23	0.60	--	1.67	1.14	--	G.C.Calib
30	Co.011	15.9	5	126	135	278	450	2.0	20	28.5	1.27	34.5	4.0	55.1	6.43	0.53	--	1.84	1.26	--	
30	Co.011	15.9	6	150	159	280	450	2.0	20	36.0	0.95	40.3	4.5	47.9	7.32	0.48	--	1.77	1.20	--	
30	Co.011	15.9	7	174	183	280	450	2.0	20	38.5	0.77	43.7	4.7	43.7	7.90	0.45	--	1.93	1.29	--	
30	Co.011	15.9	8	198	207	280	450	2.0	20	36.0	1.15	38.5	4.5	50.9	6.07	0.52	--	2.18	1.43	--	
30	Co.011	15.9	9	222	230	240	450	2.0	20	4.4	0.20	1.9	4.0	85.5	3.63	0.66	--	6.00	3.67	--	

Feed Gas Rates

Per No	N2 SLH	H2 SLH	CO SLH	Total SLH
1	558	225	112	895
2	558	225	112	895
3	558	225	112	895
4	558	225	112	895
5	558	225	112	895
6	338	135	67	540
7	250	100	50	400
8	160	160	80	400
9	558	225	112	895

Table VI
(Continued)

SUMMARY OF M4 SBOR CALSICAT CATALYST AGING RUN

a) Unless otherwise noted, total flow is ca. 15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (X).

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons, C₁+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt., g	Per No	Time Start	Time Stop	Temp C	Pres psi	H ₂ CO	Synfl cc/hr	Conv. %	Prod. Rate	Selectivities	Alpha GC	Alpha Liq	Olefin C ₃	Paraf C ₄	Olefins C ₅ -18, %	Comments
33	CAL.13	15.9	1	23	39	241	450	2.0	20	28.1	1.28	6.4 1.4 90.9 1.29	0.81	0.85	3.64	2.15	23.8	
33	CAL.13	15.9	2	47	63	240	450	2.0	20	25.4	1.21	6.7 1.3 90.8 1.17	0.81	--	3.80	2.45	--	
33	CAL.13	15.9	3	71	87	240	450	2.0	20	25.7	1.18	6.8 1.3 90.8 1.14	0.80	--	3.80	2.25	--	
33	CAL.13	15.9	4	95	111	240	450	2.0	20	25.1	1.15	6.7 1.4 90.6 1.24	0.80	--	4.33	2.55	--	
33	CAL.13	15.9	5	119	135	238	450	2.0	20	22.4	1.02	5.7 1.4 91.8 1.14	0.80	--	4.25	2.50	--	
33	CAL.13	15.9	6	143	159	243	450	2.0	20	27.4	1.25	7.9 1.7 89.0 1.40	0.79	--	3.54	2.13	--	
33	CAL.13	15.9	7	162	178	240	450	2.0	20	23.8	1.09	6.4 1.5 91.0 1.13	0.80	--	4.88	2.55	--	
33	CAL.13	15.9	8	186	203	240	450	2.0	20	22.5	1.03	6.3 1.6 91.1 1.07	0.79	--	4.50	2.60	--	G.C. Calib
33	CAL.13	15.9	9	210	231	241	450	2.0	20	23.2	1.06	6.7 1.6 90.5 1.12	0.81	0.86	4.22	2.45	25.2	
33	CAL.13	15.9	10	234	255	240	450	2.0	20	21.9	1.00	6.4 1.6 90.9 1.05	0.79	--	4.50	2.78	--	
33	CAL.13	15.9	11	262	279	240	450	2.0	20	22.0	1.00	6.3 1.6 91.1 1.02	0.80	--	4.37	2.50	--	
33	CAL.13	15.9	12	282	303	240	450	2.0	20	21.4	0.98	6.1 1.5 91.4 1.01	0.80	--	4.25	2.78	--	
33	CAL.13	15.9	13	306	327	240	450	2.0	20	20.1	0.92	5.9 1.6 91.5 1.05	0.80	--	4.71	2.56	--	
33	CAL.13	15.9	14	331	351	240	450	2.0	20	20.3	0.93	6.0 1.7 91.1 1.12	0.79	--	4.13	2.67	--	
33	CAL.13	15.9	15	360	373	240	450	2.0	20	18.5	0.85	7.2 1.5 90.3 0.98	0.80	--	4.20	3.00	--	G.C. Calib
33	CAL.13	15.9	16	385	398	240	450	2.0	20	19.8	0.91	6.8 1.4 90.8 1.02	0.79	0.85	4.71	2.40	24.5	
33	CAL.13	15.9	17	402	423	240	450	2.0	20	18.4	0.84	7.5 1.6 89.9 1.09	0.78	--	4.00	2.50	--	
33	CAL.13	15.9	18	428	447	239	450	2.0	20	17.2	0.78	7.1 1.6 90.3 1.06	0.78	--	4.43	2.88	--	
33	CAL.13	15.9	19	510	519	241	450	2.0	20	15.6	0.71	6.9 1.5 90.6 1.11	0.78	--	4.67	2.63	--	Down 48hr
33	CAL.13	15.9	20	522	543	241	450	2.0	20	14.5	0.66	6.8 1.2 91.1 0.88	0.77	--	4.50	3.00	--	
33	CAL.13	15.9	21	546	567	240	450	2.0	20	14.0	0.64	6.9 1.2 91.1 0.76	0.77	0.88	5.40	3.00	26.6	
33	CAL.13	15.9	22	570	591	240	450	2.0	20	13.6	0.62	6.9 1.5 90.7 0.98	0.77	--	5.40	3.00	--	
33	CAL.13	15.9	23	596	614	240	450	2.0	20	14.1	0.64	7.0 1.5 90.6 0.95	0.77	--	4.50	3.00	--	
33	CAL.13	15.9	24	617	638	240	450	2.0	20	13.5	0.62	7.0 1.5 90.6 0.87	0.77	--	5.40	2.86	--	
33	CAL.13	15.9	25	641	662	240	450	2.0	20	13.1	0.60	7.1 1.5 90.5 0.86	0.76	--	6.50	2.86	--	
33	CAL.13	15.9	26	665	686	240	450	2.0	20	12.8	0.59	7.3 1.4 90.6 0.73	0.76	--	5.20	2.86	--	
33	CAL.13	15.9	27	689	710	240	450	2.0	20	12.6	0.58	7.2 1.4 90.5 0.86	0.76	--	5.20	2.86	--	
33	CAL.13	15.9	28	713	734	240	450	2.0	20	12.4	0.57	7.5 1.6 90.0 1.01	0.76	0.84	5.20	2.86	25.9	
33	CAL.13	15.9	29	737	758	240	450	2.0	20	12.4	0.57	7.6 1.5 90.2 0.74	0.76	--	5.20	2.86	--	
33	CAL.13	15.9	30	761	782	241	450	2.0	20	12.3	0.56	7.9 1.6 89.6 0.82	0.76	--	5.20	3.00	--	
33	CAL.13	15.9	31	785	806	241	450	2.0	20	12.3	0.56	7.8 0.7 90.9 0.52	0.76	--	6.50	2.86	--	
33	CAL.13	15.9	32	811	830	241	450	2.0	20	12.0	0.55	7.7 1.1 90.6 0.61	0.75	--	6.50	2.86	--	
33	CAL.13	15.9	33	833	854	240	450	2.0	20	11.7	0.54	7.7 1.5 90.1 0.74	0.75	--	5.20	2.86	--	
33	CAL.13	15.9	34	857	878	241	450	2.0	20	11.8	0.54	8.0 0.6 91.0 0.50	0.76	--	6.50	2.86	--	
33	CAL.13	15.9	35	881	902	240	450	2.0	20	11.5	0.53	8.0 0.3 91.2 0.47	0.76	--	6.50	2.86	25.9	
33	CAL.13	15.9	36	905	926	240	450	2.0	20	11.3	0.52	8.6 1.1 89.9 0.44	0.75	--	6.50	3.17	--	
33	CAL.13	15.9	37	929	950	240	450	2.0	20	11.3	0.52	8.8 1.3 89.5 0.46	0.75	--	6.50	3.17	--	
33	CAL.13	15.9	38	953	974	240	450	2.0	20	11.3	0.52	9.2 1.6 88.4 0.81	0.74	--	5.00	2.71	--	
33	CAL.13	15.9	39	977	998	240	450	2.0	20	11.3	0.52	9.3 1.6 88.4 0.75	0.75	--	5.00	3.33	--	
33	CAL.13	15.9	40	1001	1022	241	450	2.0	20	10.8	0.49	10.2 0.8 88.4 0.52	0.74	--	5.00	2.86	--	
33	CAL.13	15.9	41	1031	1046	241	450	2.0	20	12.9	0.60	9.3 0.0 90.7 0.00	0.77	--	5.40	3.00	--	
33	CAL.13	15.9	42	1049	1069	240	450	2.0	20	11.2	0.52	9.4 0.6 89.6 0.37	0.75	--	5.50	2.86	22.4	

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf Olefin		
---	---	---	---	---	%CH4	%C2	%C3+	%CO2	---	---	C3	C4	C5-18, %
3	CO.002	15.2	29.4	1.42	17.3	2.3	79.4	1.01	0.73	0.82	0.91	0.60	17.5
4	CO.024	15.4	25.5	1.21	8.6	2.0	89.0	0.43	0.79	0.84	2.93	1.93	21.7
5	CO.035	15.4	24.8	1.18	8.5	2.1	89.0	0.47	0.78	0.84	3.13	1.94	23.1
6	CO.028	15.4	21.2	1.00	6.1	1.6	91.3	1.01	0.81	0.83	4.86	3.00	28.7
7	CO.043	15.4	13.0	0.61	3.7	1.8	93.4	1.06	0.79	0.85	5.60	3.17	27.3
8	CO.006	15.0	2.7	0.25	0.1	0.2	98.8	1.75	0.67	0.85	3.33	2.33	16.1
9	CO.048	15.4	19.1	0.90	9.9	1.6	87.4	1.05	0.77	0.88	3.60	2.09	20.3
10	CAL.02	15.9	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.81	1.66	1.06	21.0
11	CAL.03	15.6	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	1.65	1.03	18.2
12	CO.053	15.9	34.2	1.56	12.6	2.0	84.2	1.23	0.75	0.83	1.60	1.00	24.5
13	CO.054	15.7	10.4	0.48	4.7	1.8	92.3	1.17	0.78	0.86	5.75	4.00	25.9
14	BlendA	20.0	29.3	1.41	10.1	1.6	86.3	2.02	0.77	0.86	2.23	1.35	23.1
15	CO.034	13.0	27.5	1.54	10.4	1.6	87.2	0.80	0.78	0.84	2.21	1.40	21.0
16	CAL.04	16.1	26.3	1.34	7.1	1.3	90.3	1.38	0.80	0.85	4.80	3.18	32.9
17	CAL.08	15.0	16.9	0.93	5.9	1.0	91.7	1.36	0.82	0.88	5.20	3.33	28.7
18	CAL.07	15.0	20.6	1.03	7.7	1.2	90.0	1.09	0.81	0.88	5.00	3.00	32.2
19	CAL.05	15.7	26.6	1.22	7.3	1.3	90.2	1.19	0.82	0.86	4.11	3.00	28.7
20	CAL.06	15.0	5.6	0.26	3.1	2.1	92.0	2.86	0.80	0.90	4.50	3.50	30.8
21	CO.004	15.9	39.3	1.80	15.2	2.3	81.2	1.38	0.74	0.80	1.16	0.73	23.1
23	CAL.09	15.0	17.4	0.84	0.0	1.2	97.9	0.95	0.83	0.88	5.40	3.33	29.4
24	CO.053	28.5	50.4	1.28	14.1	2.1	81.8	2.03	0.75	0.79	1.14	0.68	21.7
25	CO.056	15.0	11.4	0.55	7.8	3.6	87.2	1.43	0.67	0.87	3.60	2.30	20.3
26	CAL.10	15.6	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	3.60	2.27	25.9
27	Co.050	14.6	20.4	1.01	6.8	1.9	90.2	1.04	0.78	0.87	2.50	1.69	18.9

Note: Catalysts for Runs 3 thru 15 (except 8) screened through 150 x 400 mesh.

Catalyst for Run 8 screened thru 100 x 400 mesh.

Cat. Nos. CAL.08 and CAL.07 were prereduced and coated with wax.

H2 to CO ratio for Runs 16 and 17 was 1.76/1.0.

Cat. No. CAL.06 was H2 reduced and air stabilized.

Cat. No. CAL.09 was prereduced and coated with Soya.

Table VII
(Continued)

DATE: 03/31/95

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf		
---	---	---	---	---	%CH4	%C2	%C3+	%CO2	---	---	C3	C4	C6-18, %
28	CO.057	15.8	18.7	0.86	5.3	1.5	92.2	0.98	0.81	0.85	3.27	2.36	23.1
29	Co.061	45.4	29.0	0.46	14.4	2.6	81.6	1.53	0.72	0.80	1.49	0.94	18.9
30	Co.011	15.9	8.0	0.36	5.8	3.9	87.8	2.49	0.71	0.89	5.75	3.00	22.4
31	CAL.12	15.9	27.6	1.26	7.9	1.0	90.0	1.11	0.79	0.84	3.50	2.07	25.2
32	CAL.11	15.9	30.6	1.40	7.8	1.4	89.6	1.18	0.80	0.84	3.91	3.33	26.6
33	CAL.13	15.9	28.1	1.28	6.4	1.4	90.9	1.29	0.81	0.85	3.64	2.15	23.8

Note: Catalysts for all runs were screened thru 150 x 400 mesh.
Catalyst No. Co.061 contains 30 % cobalt.

DATE: 03/31/95

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
2	220 C	450psi	2.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-563 SLH, H2-225 SLH, CO-112.5 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat., hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin C3	Paraf C4	Olefin C6-18, %
---	---	---	---	---	%CH4	%C2	%C3+	%CO2	---	---	---	---	---
3	CO.002	15.2	11.8	0.56	4.7	1.0	93.7	0.59	0.81	0.90	2.71	1.63	--
4	CO.024	15.4	9.5	0.45	0.0	2.1	97.6	0.27	0.83	0.91	5.33	4.00	--
5	CO.035	15.4	8.8	0.42	0.0	2.3	97.4	0.31	0.82	--	5.33	4.00	--
6	CO.028	15.4	6.6	0.31	0.0	1.9	97.4	0.72	0.83	0.90	5.50	4.00	--
7	CO.043	15.4	4.3	0.20	0.0	1.4	96.3	2.25	0.81	0.91	4.00	3.00	--
9	CO.048	15.4	6.1	0.28	1.8	1.0	95.2	1.93	0.80	0.91	3.67	3.00	--
10	CAL.02	15.9	14.9	0.68	4.6	0.9	94.0	0.47	0.81	0.88	4.40	2.29	--
12	CO.053	15.9	14.4	0.66	4.3	1.0	94.3	0.48	0.81	0.89	4.20	2.67	--
13	CO.054	15.7	0.2	0.01	0.0	20.	60.8	19.5	0.33	0.94	8.00	5.00	--
14	BlendA	20.0	12.4	0.60	4.3	0.9	93.9	0.95	0.81	0.91	3.80	2.33	--
15	CO.034	13.0	11.0	0.61	4.0	0.9	94.5	0.59	0.82	0.90	4.00	3.00	--
16	CAL.04	16.1	8.4	0.42	2.6	1.0	94.1	2.31	0.80	0.88	5.00	4.00	--
17	CAL.08	15.0	5.4	0.28	0.1	0.8	96.9	2.23	0.83	--	4.00	3.00	--
18	CAL.07	15.0	6.7	0.33	1.8	1.4	95.0	1.81	0.85	--	4.00	3.00	--
19	CAL.05	15.7	9.0	0.41	2.3	1.4	94.8	1.56	0.84	--	5.50	3.00	--
20	CAL.06	15.0	3.5	0.16	0.0	3.3	92.8	3.87	0.80	0.85	3.00	2.50	--
21	CO.004	15.9	16.1	0.74	8.1	1.2	90.2	0.48	0.78	0.86	3.38	2.22	--
23	CAL.09	15.0	6.6	0.32	0.2	0.9	98.0	0.92	0.90	--	4.00	3.00	--
25	CO.056	15.0	4.5	0.22	0.3	2.7	95.7	1.27	0.73	--	4.67	3.00	--
27	Co.050	14.6	8.1	0.39	0.0	4.8	92.6	2.56	0.79	0.87	8.50	3.00	--
28	Co.057	15.8	6.0	0.28	0.0	1.8	97.2	0.93	0.79	--	5.50	4.00	--
29	Co.061	45.4	11.8	0.19	3.9	1.9	93.5	0.73	0.77	--	3.67	2.29	--

Note: Catalysts for Runs 3 through 15 screened thru 150 x 400 mesh.

Blend A contains 15.0 gm of Cat. No. CO.005 plus 5.0 gm of Cat. No. WGS.03.

Cat. NOS. CAL.08 and CAL.07 were prereduced and wax coated.

H2 to CO for Runs 16 and 17 was 1.76/1.0.

Cat. No. CAL.06 was H2 reduced and air stabilized before charging.

Cat. No. CAL.09 was prereduced and coated with Soya.

Cat. No. Co.061 contains 30 % cobalt.

DATE: 03/31/95

M4 SBCR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H2/CO Ratio
-----	-----	-----	-----
4	240 C	450psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

Flows: N2-562 SLH, H2-119 SLH, CO-119 SLH

b) Conversion is total CO conversion over the period (%).

c) Conversion and selectivities are calculated using N2 as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C1+ (kg/kg cat.,hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt, g	Conv. %	Prod. Rate	Selectivities	Alpha GC	Alpha Liq	Olefin/Paraf C3	Olefin C4	Olefin C6-18, %
---	---	---	---	---	%CH4 %C2 %C3+ %CO2	---	---	---	---	---
3	CO.002	15.2	11.6	0.83	3.9 2.4 92.8 0.84	0.81	0.87	4.29	3.14	--
4	CO.024	15.4	10.3	0.73	0.5 1.6 97.2 0.71	0.83	0.87	8.33	4.75	--
5	CO.035	15.4	10.4	0.73	0.9 0.0 98.4 0.65	--	0.83	--	--	--
6	CO.028	15.4	9.2	0.65	0.0 1.3 97.3 1.46	0.85	0.88	9.50	3.75	--
7	CO.043	15.4	5.2	0.37	0.0 0.0 99.4 0.64	0.83	0.89	7.00	5.00	--
9	CO.048	15.4	8.2	0.57	2.3 1.0 93.8 3.00	0.82	0.90	8.50	4.33	--
10	CAL.02	15.9	14.6	1.00	4.6 1.0 93.3 0.97	0.80	0.88	7.20	4.00	--
12	CO.053	15.9	13.3	0.91	4.3 1.2 93.3 1.18	0.80	0.89	6.60	3.71	--
13	CO.054	15.7	5.2	0.36	0.0 1.2 97.0 1.85	0.83	0.95	6.00	4.50	--
14	BlendA	20.0	12.7	0.91	3.4 1.0 94.0 1.61	0.81	0.86	7.50	3.83	--
15	CO.034	13.0	11.2	0.94	3.9 1.0 94.0 1.02	0.82	0.87	8.33	4.00	--
21	CO.004	15.9	14.9	1.02	7.4 1.4 89.9 1.29	0.77	0.84	4.67	2.82	--
27	Co.050	14.6	8.4	0.61	1.1 2.9 93.3 2.78	0.79	0.90	6.25	5.00	--
28	Co.057	15.8	8.1	0.56	1.3 4.6 92.7 1.44	0.79	--	7.33	5.67	--

Note: Catalysts for Runs 3 through 21 screened thru 150 x 400 mesh.

DATE: 03/31/95

M4 SBGR RUN RESULTS

COMPARISON OF CATALYST ACTIVITY AT SIMILAR RUN CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
5	240 C	600psi	1.0

a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.

b) Conversion is total CO conversion over the period (%).

Flows: N₂-562 SLH, H₂-119 SLH, CO-119 SLH

c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.

d) Prod. rate: Rate for production of total hydrocarbons C₁+ (kg/kg cat.,hr).

e) Alpha: Based on GC analysis of offgas and liquid product.

Run No	Cat. No	Cat. wt,g	Conv. %	Prod. Rate	Selectivities				Alpha GC	Alpha Liq	Olefin/Paraf C ₃	Olefin C ₄	Olefin C ₆₋₁₈ , %
---	---	---	---	---	%CH ₄	%C ₂	%C ₃ +	%CO ₂	---	---	---	---	---
3	CO.002	15.2	12.9	0.92	4.0	1.5	93.5	0.91	0.81	0.82	4.29	2.75	24.5
4	CO.024	15.4	11.3	0.80	0.9	1.5	97.0	0.65	0.83	0.87	6.50	3.80	36.4
5	CO.035	15.4	10.7	0.76	0.7	1.4	97.1	0.75	0.84	0.88	6.25	4.50	27.3
6	CO.028	15.4	9.5	0.67	0.0	1.1	97.5	1.36	0.85	0.88	6.00	3.50	40.6
7	CO.043	15.4	5.9	0.41	0.0	2.2	94.8	2.99	0.82	0.89	6.00	3.75	30.1
9	CO.048	15.4	11.9	0.83	2.7	0.9	94.4	1.93	0.84	0.89	5.75	3.20	14.0
10	CAL.02	15.9	16.4	1.12	4.2	1.0	94.0	0.89	0.82	0.86	5.83	3.86	35.7
12	CO.053	15.9	15.6	1.06	4.0	0.9	94.0	1.0	0.82	0.87	5.50	3.57	32.2
13	CO.054	15.7	5.0	0.34	0.0	1.3	96.9	1.78	0.82	0.93	6.50	3.33	30.8
14	BlendA	20.0	14.1	1.02	3.7	1.0	93.8	1.45	0.82	0.89	6.40	3.43	32.9
15	CO.034	13.0	11.8	0.99	3.9	1.1	94.0	1.03	0.83	0.87	5.75	3.80	37.8
21	CO.004	15.9	18.4	1.26	6.1	1.1	91.9	0.94	0.81	0.84	5.25	2.91	32.2

Note: Catalysts for Runs 3 through 21 screened thru 150 x 400 mesh.

Table XI

DATE: 03/31/95

COMPARISON OF CONVERSION AND SELECTIVITY OF
CALSIKAT PRODUCED CATALYSTS AT STARTUP CONDITIONS

Period No.	Temp.	Pres.	H ₂ /CO Ratio
-----	-----	-----	-----
1	240 C	450psi	2.0

- a) Total flow is ca.15 L/min. STP, or 3 cm/sec linear gas flow.
Flows: N₂-563 SLH, H₂-225 SLH, CO-112.5 SLH
b) Conversion is total CO conversion over the period (%).
c) Conversion and selectivities are calculated using N₂ as an internal standard in the GC analysis of the offgas.
d) Prod. rate: Rate for production of total hydrocarbons C₁+ (kg/kg cat.,hr).
e) Alpha: Based on GC analysis of offgas and liquid product.

Run	Cat.	Cat.	Conv.	Prod.	Selectivities				Alpha	Alpha	Catalyst Composit.		
No	No	wt,g	%	Rate	%CH ₄	%C ₂	%C ₃ +	%CO ₂	GC	Liq	Prom%	Metal%	Suppt

M-4 SBCR													
10	CAL.02	15.9	34.5	1.58	12.9	2.0	83.9	1.23	0.75	0.81	0.0	0.5Ru	Al
11	CAL.03	15.6	29.7	1.39	13.5	2.1	83.4	1.08	0.74	0.86	0.0	0.5Ru	Al
16	CAL.04	16.1	26.3	1.34	7.1	1.3	90.3	1.38	0.80	0.85	0.3K	0.5Ru	Al
17	CAL.08	15.0	16.9	0.93	5.9	0.8	91.7	1.36	0.82	0.88	0.3K	0.5Ru	Al
18	CAL.07	15.0	20.6	1.03	7.7	1.2	90.0	1.09	0.81	0.88	0.3K	0.5Ru	Al
19	CAL.05	15.7	26.6	1.22	7.3	1.3	90.2	1.19	0.82	0.86	0.3K	0.5Ru	Al
20	CAL.06	15.0	5.6	0.26	3.1	2.1	92.0	2.86	0.80	0.90	0.3K	0.5Ru	Al
23	CAL.09	15.0	17.4	0.84	0.1	1.2	97.9	0.95	0.83	0.88	0.3K	0.5Ru	Al
26	CAL.10	15.6	21.9	1.01	5.4	1.5	91.9	1.25	0.79	0.85	0.3K	0.5Ru	Al
31	CAL.12	15.9	27.6	1.26	7.9	1.0	90.0	1.11	0.79	0.84	0.3K	0.5Ru	Al
32	CAL.11	15.9	30.6	1.40	7.8	1.4	89.6	1.18	0.80	0.84	0.3K	0.5Ru	Al
33	Cal.13	15.9	28.1	1.28	6.4	1.4	90.9	1.29	0.81	0.85	0.3K	0.5Ru	Al

M-3 SBCR

12	CO.018	15.6	33.8	1.56	9.7	2.0	86.6	1.68	0.75	0.85	0.0	0.5Ru	Al
23	CO.047	15.8	28.2	1.29	7.7	1.5	89.3	1.47	0.79	0.84	0.3K	0.5Ru	Al

Note: Catalysts for all runs except Runs 17,18,& 20 screened thru 150 x 400 mesh.

Catalyst CAL.04 was calcined in air; Catalyst CAL.05 processed in N₂.
Cat. No. CAL.06 was H₂ reduced and air stabilized before charging.
Cat. Nos. CAL.08 and CAL.07 were prereduced and wax coated. CAL.08 was calcined in N₂; CAL.07 was reduced in H₂ without prior calcination.
H₂ to CO ratio for Runs 16 and 17 was 1.76/1.
Cat. Nos. Co.018 & Co.047 were prepared by Pitt. Shown for comparison.
Cat. No. CAL.09 was prereduced and coated with Soya.
Cat. No. CAL.10 was prepared on Condea Alumina.